Production and Delivery

Summary of Annual Merit Review Hydrogen Production and Delivery Subprogram

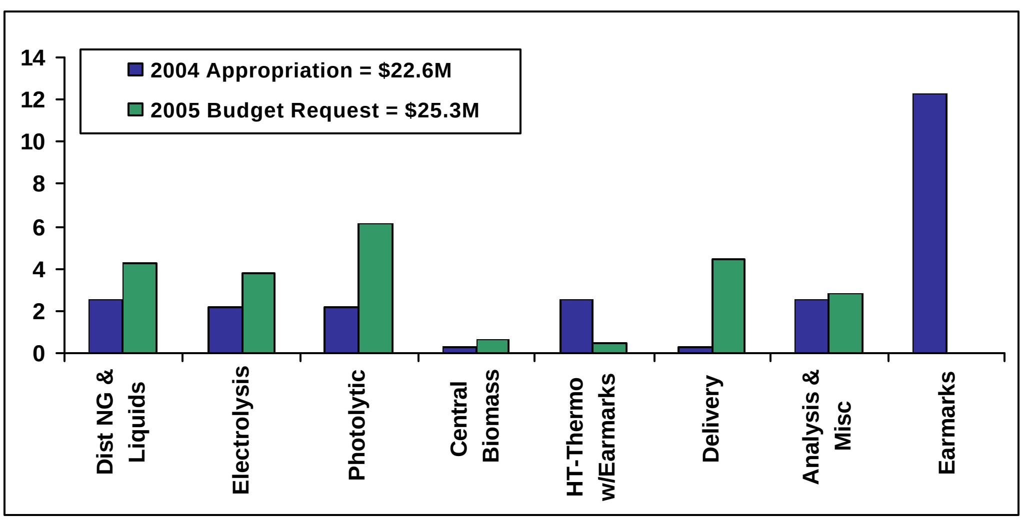
Summary of Reviewer Comments on Production and Delivery Subprogram:

Reviewers identified the Production and Delivery Technologies Subprogram to be an essential component to the Hydrogen Program mission, and critical to the success of the President's Hydrogen Fuel Initiative. The production and delivery projects are considered to be appropriately diverse and strongly focused on addressing key issues necessary to reach technical targets.

In general, the reviewers noted that the Production and Delivery Subprogram has good coverage of possible paths to production, progress was made towards goals from 2003, and the Subprogram has a well-balanced portfolio. Some reviewers commented that projects have made significant progress toward technology commercialization.

The major concerns identified in some areas by reviewers were: 1) collaboration roles with other research organizations need to be clarified; 2) key assumptions underlying process economics need to be stated; 3) criteria for project success need to be better defined; and, 4) specific technology development needs to be reviewed as part of an overall hydrogen energy system. Reviewers further identified the need for increased clarity in economic evaluations including price assumptions and "per mile" costs.

Hydrogen Production and Delivery Funding by Technology:



Majority of Reviewer Comments and Recommendations:

In general, the reviewer scores for the Production and Delivery Subprogram are comparable with or slightly higher than those of the other Subprograms (the maximum, minimum, and average scores for Production and Delivery are 3.53, 2.20, and 3.00, respectively). These scores compare to the overall Hydrogen Program maximum, minimum, and average project scores of 3.92, 1.55, and 2.92, respectively. The Production and Delivery Subprogram portfolio includes a mix of projects, from well-defined research activities that are succeeding to new projects with little to no progress or technical accomplishments yet to report.

The major recommendations for the Production and Delivery Subprogram are summarized below. DOE will act on reviewer recommendations as appropriate for the overall Hydrogen Production and Delivery effort.

- **Separations:** Some reviewers stated that DOE should focus on using advanced separations technologies to improve the economics of small-scale distributed systems and clarify if membrane fabrication costs are included in the material cost targets. Other reviewers said that the costs and commercial viability of membrane reactor systems should be considered.

- **Distributed Production Technologies:** The reviewers stated DOE should focus on applications that produce high-purity hydrogen for PEM fuel cells by improving the amount of hydrogen separated per mole of methane and de-emphasize partial oxidation processes that produce less hydrogen per mole of methane.

- **Photobiological**: Reviewers commented that the projects in this area were tightly focused on overcoming very specific barriers at the possible expense of meeting longer-term goals. Overall, the reviewers felt that systems analysis and engineering should be performed in this technology area to determine whether success could lead to meeting DOE hydrogen production goals of being competitive with traditional fuels. Reviewers saw good collaboration and progress.

- **Photoelectrochemical:** Sufficient funding in this area for long term development is lacking, however some progress was made since last year. A concern of reviewers is that this area represents a “splintered” collection of smaller projects, and that a dedicated, multi-disciplinary program that is well organized and integrated should be put in place.

- **Electrolysis**: The reviewer comments were generally favorable in the area of regenerative solid-oxide electrolyzer cells for hydrogen production from steam, but future work plans had not been defined. Technology transfer and collaboration got lower ratings from reviewers. The advanced electrolysis work received lower scores primarily because there are new projects in this area and not much progress had been made.

- **High Temperature Thermochemical:** The reviewer comments were generally favorable for projects in this area. The analytical approach to screening all possible solar driven thermochemical cycles against well chosen criteria and establishing a public database for this information was viewed positively. Some concern was raised that too much effort was placed on analytical screening and not enough effort on experimental work. The reviewers viewed this approach to hydrogen production as important to pursue.

- **Biomass:** The reviewers raised concerns that there are several projects in the biomass pyrolysis reforming area that could be combined with clearer focus on the program goals.

Reviewers also had concern over the small degree of progress, although most of the projects in this area began this year.

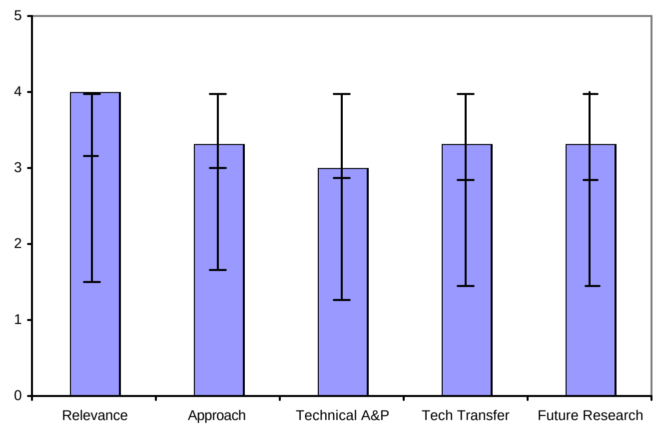
- **Analysis:** This area received generally high scores from reviewers. The reviewers suggested developing consensus forecasts in major scenarios depicting different types of transitions, e.g. import reduction, fossil reduction, and alternate energy breakthroughs. Good technology transfer and collaboration was recognized and the results appear to be useful tools. Future work needs to be defined.

Project # HPD-1: Hydrogen Production and Delivery Subprogram Overview
Devlin, Pete; DOE, Team Lead

Brief Summary of Presentation

The purpose of this Hydrogen Production and Delivery Subprogram Overview and introduction is to describe subprogram goals/objectives, budgets, barriers/targets, approach to R&D, technical accomplishments, interactions and collaborations, solicitations and awards, and future directions. As such, it sets the stage and puts into context the R&D and analysis projects which will be presented in this subprogram area during the Annual Merit Review.

Overall Project Score: 3.40



Question 1: Relevance to overall DOE objectives

This presentation earned a score of **4.00** for its relevance to DOE objectives.

- A good overview for audience members not overly familiar with this particular subprogram.
- Good summary presentation. Split shown among near and long-term R&D, with different targets and goals. Good summary of key barriers in each.
- Production: at what pressure?
- Resource Price Assumption - Delivery: per mile? At what pressure? Pipe? On-site?
- Very clear -- targets, quantitative, gains, and challenges clearly described.

Question 2: Approach to performing the research and development

This presentation was rated **3.33** on its approach.

- Electrolysis should be compared with battery as storage technology.
- Impact of natural gas demand needs attention- transition must be managed.
- Overall natural hydrogen production goals need to be set.
- Confirm a detailed roadmap has been/ will be developed for each identified barrier.
- "Sharply focused" does not apply, but a portfolio approach is exactly what is called for.
- Challenges clearly described. Plans described, but unclear as to how plans address challenges.
- Judging from the TDM presentation, I would say it is good. However, this was not reflected in all the talks that followed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This presentation was rated **3.00** based on accomplishments.

- More details on accomplishments would have been useful- annual progress as well as comparison with target.
- Key milestones were noted to be measured against a "design" as opposed to prototype and proven.

- Confirm milestone measurement is to be used on theory (design) or proof of principal.
- Most areas making good progress.
- Delivery just started.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This presentation was rated **3.33** for technology transfer and collaboration.

- Complexities of relationships could become a barrier.
- Consider setting up competitive contest between researchers in few areas.
- Collaboration is fundamental to the effort.

Question 5: Approach to and relevance of proposed future research

This presentation was rated **3.33** for proposed future work.

- Program for selecting future projects seems effective.
- Confirm/ consider integration of coal into the fuels for conversion.
- Sidebar: I believe coal is in the plan as a solid fuel, but was not in the presentation.

Strengths and weaknesses

Strengths
- Good coverage of possible paths to production.
- Good progress in goal specification from 2003.
- Production has well-balanced portfolio.

Weaknesses
- Does not address National goals for hydrogen production. What volumes would be necessary in 2010? 2015? How does the plan address this?
- What are resource price assumptions (NG, Biomass, etc.). Tech collaboration needs further specification.
- Too many general cooperative agreements.
- H_2 production streams need to state/ pressure/ temperature specifications.
- As shown, the costs imply only cost of production, not total cost. Although the focus is hydrogen, a complete picture, consider, where appropriate, showing costs of H_2 to include base fuel costs.
- All goals are set in a $ basis. Confirm what year is used as a basis for projected financial goals.
- Consider increasing design/operational pressure goals for all projects up to 15,000 - 20,000 psi. Dependent upon timing for ASME developing design, fabrication and testing requirements.
- Delivery needs definition.

Specific recommendations and additions or deletions to the work scope

- State National goals.
- Set up competition among collaborators.
- Pressure assumptions should be stated.
- Address per mile costs for delivery.
- Compare electrolysis to battery capture.
- Assess impact of natural gas demand.

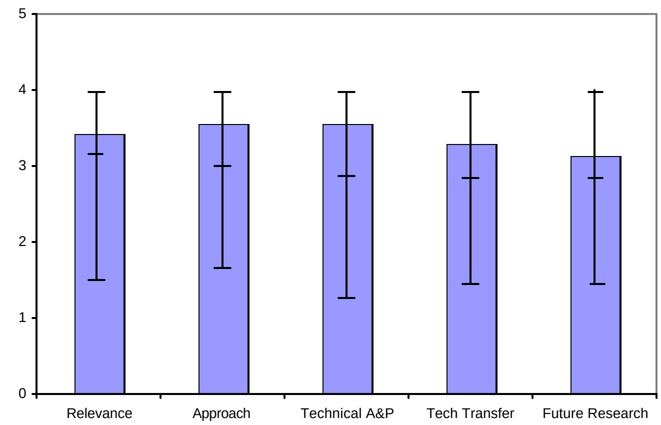
- Set annual progress goals.
- Set resource price assumptions at several levels.
- No mention of nuclear as an engine for H_2 production by thermal or electrochemical processes.
- Subprogram suggestions: (1) Establish several common benchmarked experiments for membranes, such as a "mix" to test H_2 flux, selectivity (or 2 or 3 conditions to reflect different schemes). Other areas have similar challenges to review and compare. (2) Many of the small projects plan some level of economics. Again, a common assessment and how much needed at what level, sets of baseline data of vessels/materials/electricity would help comparisons -- even if a project revises numbers based on their needs and results. (3) Examine ways to link small with larger projects, even if informally.

Project # HPD-2: Ceramic Membrane Reactor Systems for Converting Natural Gas to Hydrogen (ITM Syngas)
Chen, Christopher; Air Products and Chemicals Inc.

Brief Summary of Project

In this project, Air Products and Chemicals, Inc. is working towards developing ceramic membrane reactor systems for converting natural gas to hydrogen and synthesis gas for liquid transportation fuels. The reactor is intended to be scaled up through pilot-scale testing and pre-commercial demonstration. Technical, engineering, operational and economic data necessary for full commercialization is being collected and analyzed.

Overall Project Score: 3.40



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.43** for its relevance to DOE objectives.

- Significant development for H_2 production if successful.
- Scale of demo appropriate for project.
- Estimate of $ significance of membrane to entire process would be useful.
- A novel technology with great promises.
- Potentially an important project in meeting significant targets.

Question 2: Approach to performing the research and development

This project was rated **3.57** on its approach.

- Good engineering of compact micro channel reactor, especially mechanical design.
- Using chemical potential for O_2 to drive transport vs. change in p is a good approach.
- Good mix of basic (material development) and applied (fabrication, manufacturing) research.
- Confirm the progress plans with other (downstream) processes for such items as CO/CO_2 control and additional hydrogen purification.
- A well thought approach was presented.
- Discussions on issues related to the interfacing between oxygen transport and methane reforming could be expanded.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.57** based on accomplishments.

- Impressive results.
- Good work with PDU and increasing flux.
- Would be good to know how the economics look, i.e. how much would better flux help?

- Met target! Very encouraging.
- 39% balance of plant cost reduction is impressive.
- Creep exposure/ failure is a function of pressure, temperature, and time.
- Consider adding the time factor into the creep summary analysis; define service life at various conditions.
- Consider adding methodology for consistent creep analysis, e.g. Omega, Miller, etc.
- Maybe helpful if 05/03-05/04 accomplishments were highlighted.
- Is a housing needed for the ITM module? If so, what is the arrangement?
- No data to show the ITM performance for carrying out the methane reforming.
- Met or exceeded goals.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.29** for technology transfer and collaboration.

- Ok. Hard to evaluate with one slide but not critical.
- Role of other industrial participants were adequately discussed.
- Lots of collaborations listed, but no indication of how each is involved.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.14** for proposed future work.

- High cost/ long term project.
- Reaching the point where DOE funding should begin to be phased out.
- There's still room for improvements but there does seem to be headroom.
- Working on partial oxidation catalyst for CH_4.
- Looks good.
- Continuing according to plans.
- Good promise for generating economically viable process.
- Seal reliability key for commercial operation.
- No milestone to show the progressing of ITM performance in methane reforming, such as target goals, potential problems (if any).
- Mainly focused on scale-up/ demonstration.

Strengths and weaknesses

Strengths

- Good collaborations and interactions with others.
- Good approach and concept.
- Potentially very energy efficient.
- Good engineering and effective materials development.
- An enthusiastic PI.
- 56% industry cost share (reflects corporate commitment).
- Good approach; research carried out well.
- Shows value of integration approach rather than simply trying to develop a material that might not be fabricated into a real device.
- A very good presentation.
- Cost sharing by contractors was substantial.

- Overall solid, valuable work.

Weaknesses

- Partial oxidation produces less H_2 per CH_4 then steam reforming. This gives a H_2/CO ratio more appropriate for FT synthesis liquids.
- Lack of demonstrated time on test.
- May be less head room than the presentation implied.
- Would like to have heard what the particular barriers are to commercialization.
- Heard the good news, but wondered about possibly undiscussed bad news.
- Scope and details of the technical data presentation could be expanded.

Specific recommendations and additions or deletions to the work scope

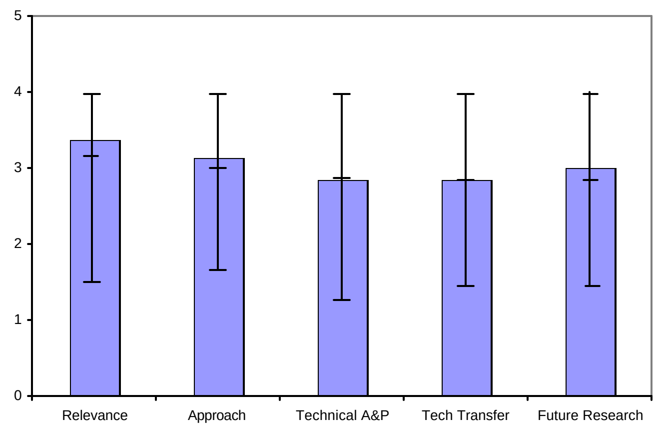
- Discuss whether this technology is applicable for distributed H_2 production or only large scale production.
- Consider showing H_2 production costs that include cost of base material, in this case, natural gas.
- Inclusion of a "conclusions" slide would be helpful.

Project # HPD-3: Integrated Ceramic Membrane System for H_2 Production
Schwartz, Joseph; Praxair, Inc.

Brief Summary of Project

In this project, Praxair, Inc. is developing an integrated ceramic membrane system for hydrogen production. The objectives of this project are to perform technoeconomic feasibility analysis for the system and define the development needed to prepare the concept for pilot testing and demonstration.

Overall Project Score: 3.05



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.38** for its relevance to DOE objectives.

- Direct relationship between project and DOE objectives not described.
- This membrane work has wide applicability in meeting H_2 production targets.
- Far from DOE targets in some cases.
- Not deeply concerned about safety criteria yet.
- Value of H_2 separation obvious to program.
- Pd membranes obvious choice of costs are reasonable.
- Combining water-gas shift reaction and H_2 separation in one step is critical in reducing H_2 production cost.
- Potentially a useful component, if targets can be met.

Question 2: Approach to performing the research and development

This project was rated **3.14** on its approach.

- Approach is focused on overcoming barriers such as thin film limitations and flux.
- Shouldn't Pd-Cu alloy be looked at?
- Though no- no go decision points were mentioned, the criteria for the decisions were not given.
- Pd-Ag technology is out-dated.
- 1.8 micrometers Pd-metal film a challenge.
- Reasonable approach.
- Not sure of novelty.
- Long history of Pd membranes for hydrogenation- none commercialized due to membrane fouling and costs.
- A well-thought approach was presented.
- Discussions could be expanded on issues related to the interfacing between water-gas-shift reaction and H_2 transport through membrane.
- Adequate approach, but not clear flux target will be met.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.86** based on accomplishments.

- Likely to not meet DOE flux goal.
- No test protocol for analyzing affects of trace impurities (H_2S, CO) on performance.
- Pace of effort seems slow and uninspired. Won't demo 50,000 hours durability for FY 2005.
- Good results on flux.
- 1% of capital is a good result.
- Difficulty with fabrication/sealing?
- Good to see what's needed for DOE flux target (1.8 microns).
- Lacks details on the technical accomplishments (e.g. substrate choice, experience with Pd alloys selection, and Pd film deposition).

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.86** for technology transfer and collaboration.

- Limited to 2 performing partners.
- Why internal development of support tube? Vendors exist (Pall, Moot), but were not utilized.
- Commercialization is within the realm of the contractor.
- Research institute is leveraged.
- PI stated intention to add partners as needed.
- Praxair seems resistant to partnering.
- Limited collaboration, but not critical.
- Might look for alloy (S or CO tolerance) or WGS experts in universities or National Labs if internal experts aren't available.
- Praxair has assembled a good team.
- Who is to provide water-gas-shift reaction expertise? Is it needed?
- Not a large number of collaborators, but good interaction.
- Might benefit from collaboration with someone with a better membrane technology.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Key test information lacking.
- Clear understanding of need to meet targets or get on to something else.
- Emphasis on the "reasonable time frame."
- Doing reaction may be much more difficult due to fouling.
- Should consider fabrication costs- are they comparable to materials costs?
- Contaminant work will be critical.
- A good plan to include critical steps.
- Performance targets for the HTM were not adequately discussed e.g. hydrothermal stability, durability.

Strengths and weaknesses

Strengths

- Good progress in past year.
- Clear goals.
- Clear go/no-go measures.
- Cohesive project.
- Good approach and results look promising.
- Next year should identify barriers.
- Has made good progress since May 03.

Weaknesses

- Partial oxidation produces less H_2 per CH_4 than steam reforming.
- Choice of membrane material prone to react with H_2S/CO.
- Process economics not presented -- how were they arrived at?
- Seems to have high risks for failure.
- Need to define criteria for success.
- Not sure how much fundamental work has been done to look at potential problems and approaches to optimizing alloys.
- Discussions on the water-gas-shift reaction were not adequate (catalyst choice, reaction type).
- Inclusion of a "conclusions" slide would be helpful.
- Not clear that this technology can meet flux target.

Specific recommendations and additions or deletions to the work scope

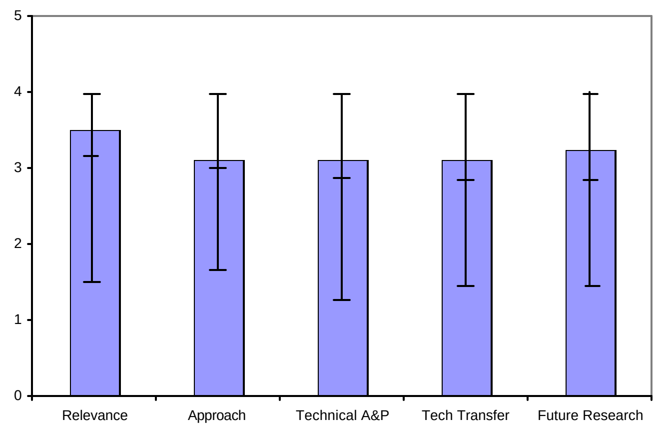
- Effect of contaminants should be looked at soon -- CO and S in particular.
- Applicable to steam reforming?
- Suggest WGS catalyst partner as a good idea.
- Need new membrane material.
- Systems approach -- make sure work is focused on the total system, including catalysts, operating temps.
- Consider collaboration with HPD-5 or HPD-7 projects.

Project # HPD-4: Low Cost Hydrogen Production Platform
Aaron, Tim; Praxair, Inc.

Brief Summary of Project

In this project, Praxair, Inc. is working towards the development of a low cost hydrogen production platform. Their efforts include defining process/equipment concepts and developing preliminary designs suitable for mass production of a small on-site hydrogen system; performing a technoeconomic study; and developing business cases regarding the viability of the development project. Using steam methane reforming and purification process technologies as the base case, they will evaluate different systems and identify the system most likely to be commercially viable when mass produced.

Overall Project Score: 3.22



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Very useful for intermediate need for distributed H_2 production.
- Objectives need to be more clearly stated.
- Project appears to integrate a system, which is relevant, but little detail is given.
- DFMA approach is relevant.
- Good for near term optimization of existing technology.
- A very useful study to guide future R&D work.
- Useful study of significant portion of an important system.

Question 2: Approach to performing the research and development

This project was rated **3.12** on its approach.

- Very practically oriented.
- Weak in the "research" aspects.
- Approach light on details.
- Used best practice engineering design approach.
- Not much detail on approach.
- Packaging of the off-the-shelf technologies.
- 33% cost share by Praxair.
- Design for manufacturing and assembly is good tool for program.
- Should give estimate of best costs for existing technologies.
- Good look at what's required for total system vs. components.
- Relationship between this project and the H_2 refueling stations in operation was not adequately discussed.

- Should have included compression, storage and dispensing in scope of this project; participation in other projects does not have the focus on DFMA that this project has.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.12** based on accomplishments.

- Making good progress toward a very practical approach for distributed H_2 production.
- Good progress towards meeting cost targets.
- It looks like cost targets will not be achievable within constraints of this project.
- Close to meeting 2005 cost target, have already met target at some sizes.
- Not obvious how much has been added from last year given large increase in spending.
- Probably significant progress, but isn't necessarily evident.
- How much were savings on high temp component?
- Hiatus due to late funding seems to have slowed project down.
- Improvement in optimized system (reduced mass of system, reduced parts and assembly complexity, and increased thermal efficiency) was not quantified.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.12** for technology transfer and collaboration.

- Technology transfer/collaboration generally not applicable.
- No university or National Lab involvement, but industry participants are highly qualified.
- ISO work valuable.
- Probably no need for academics.
- DFMA expertise in universities?
- Good collaboration between a few participants.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- On target.
- This is brute force engineering, not much innovation.
- Looks good.
- On track.
- Demonstration-focused.
- Appropriate for chosen scope.

Strengths and weaknesses

Strengths
- Related Praxair activities aid the project.
- Although not strongly research-oriented, a high value project.
- Good collaborations and progress!
- Best possible approach.
- Economic evaluations done periodically to gauge progress.
- The product should work (i.e. make hydrogen).

- Good basic approach for minimizing costs.
- Thorough integration.
- A useful study to show incremental improvement in the proposed system.
- Addresses a useful issue using current technology.

Weaknesses

- What are the innovations that contribute to achievement of the DOE goal?
- Will it really turn out to be "low cost?"
- Innovations for the proposed work were not adequately discussed.
- Inclusion of a "conclusions" slide would be helpful.
- Application of DFMA to compression/storage/dispensing would have been a valuable addition.

Specific recommendations and additions or deletions to the work scope

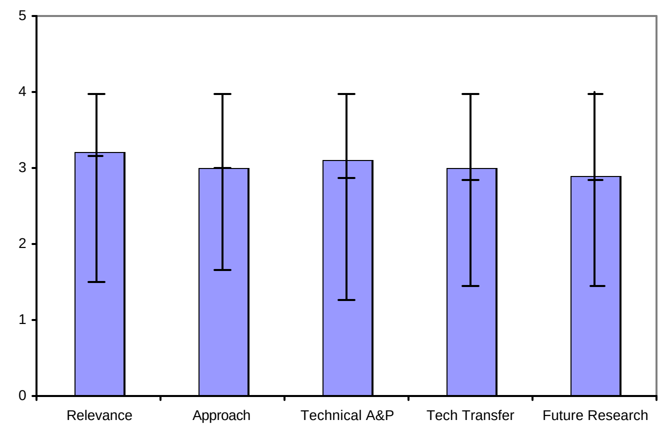
- Other organizations working on similar units - how do they compare?
- Evaluate impact of new technologies such as membranes on cost projections.
- Would benefit from extension to potential new technologies (Praxair H_2 membrane)?
- Improvement potential in compression, storage, and dispensing, if any, should be discussed.
- Expand to a complete package (compression/storage/dispensing).
- Can interactions between this project and ongoing refueling stations be increased?

Project # HPD-5: Defect-free Thin Film Membranes for H_2 Separation & Isolation
Nenoff, Tina; Sandia National Laboratories

Brief Summary of Project

In this project, Sandia National Laboratories (SNL) is working towards synthesizing defect-free thin film membranes for H_2 separation and isolation which can replace existing expensive and fragile Pt catalysts. This work includes testing the separation of light gases (pure and mixtures) through the membranes and demonstrating effective light gas separations and commercialization potential of zeolite membranes. SNL will model the permeation of light gases through various frameworks/pores for optimized performance and validate them with actual permeation data obtained through tests on a unique in-house permeation unit.

Overall Project Score: 3.04



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.22** for its relevance to DOE objectives.

- Goal is clear and holds promise.
- Membrane separation of H_2 is relevant and likely critical to achieving the objectives, but the project's focus on real-world application was not readily apparent.
- More of a science program.
- Not clear exactly where it fits into the vision in the near term.
- Probably longer range solution-higher risk than some other membrane technologies.
- Effectiveness of zeolite to separate/purify hydrogen has yet to be established.
- Potentially a useful component.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Test procedures need to be flushed out with discussion on temperature, pressure, sensitivities (impurities).
- Barriers identified and comprehensively addressed.
- Fostering industrial contacts is important, and a systems analysis component of the project should be considered to meet the challenges in operation of a fuel processor.
- Conceptually well thought out approach. But is it really producing "defect free" films?
- Steam stability at 600C? What is the critical selectivity required. Selectivity doesn't not seem that high.
- How does this compare to other ceramic membranes?
- Good balance of membrane materials synthesis and testing.

- Confirm the process plans to the interface with other (up and downstream) processes for CO/CO_2 control and additional hydrogen purification.
- No comments were made in comparing the zeolite film growth technique used in this work with those by other researchers.
- Importance of temperature on zeolite performance was not discussed adequately. Will 300C (FY 05 plan) be the optimum temperature?
- Good work on fundamental understanding to date.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.11** based on accomplishments.

- Project more focused than last year.
- Explain separation factor so audience knows what it means and its impact.
- Issue of tests at various temperatures addressed.
- Making progress in determining selectivity, temperature effects.
- Good progress for $200K.
- In some sense, the project is approaching a few of the key performance indicators.
- Good work measuring selectivities and evaluating membranes.
- H_2S and H_2O work good.
- Some very good H_2/CO_2, CO, CH_4 separation selectivities with missed vis-à-vis pure gases. But this means that membrane performance prediction, i.e., its engineering modeling will be a challenging problem, but one that has to be touched.
- Technical details were inadequate (e.g., substrate choice, film deposition technique and significance of "defect filled" and "defect free").
- Have made good progress on most of approach to date, need to move on to a specific application, rather than hypothetical gas mixtures.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Interactions appear appropriate for this project.
- Are any of the industrial partners actually potential customers of the technology? If not, they should be.
- Good partnership with university for meeting and simulation.
- Visibility in research community is good.
- Getting "free" materials from informal collaborators.
- Forging university collaborations.
- Good publication record.
- Ok.
- Pall is a good partner.
- High temperature collaboration is key.
- A number of collaborators.
- The PI is trying to make things happen.
- Presentations, but no real collaboration. Would benefit from collaboration to move the technology along.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.89** for proposed future work.

- Focus on testing.
- Obvious "voids" from work in 03/04 now identified.
- Future work plan is appropriate.
- There may be better ways to create a non-porous film architecture (on a suitable support) than this project is focused on.
- Keep tight focus.
- Move to high temperature is critical.
- Modeling is critically needed for understanding and hence predicting membrane performance with mixed gases.
- Good plan to do membrane testing at elevated temperature.
- Heading in the right direction.

Strengths and weaknesses

Strengths
- Beneficial partnerships.
- Work focused on more promising means of success and objective of lowering process cost.
- Enthusiastic PI.
- Well executed.
- Novel membrane approach for H_2.
- Project is proof of principle.
- Zeolite membrane performance data were reported.
- Promising piece of the puzzle.

Weaknesses
- Low temperature membrane - what is working range of temperature and pressure?
- Zeolites are steam sensitive - is this taken into consideration?
- Will $Si(OH)_4$ be an issue?
- Testing appears to be all low temperature - makes this difficult to compare with other technologies.
- How does this membrane's performance compare to others - Pd, microporous, proton transport?
- Low pressure; insufficient H_2 purity.
- Microstructure quality an issue.
- GC analysis may be better than RGA for gas analysis.
- Material balances?
- Inclusion of "conclusions" slide would be helpful.
- Lack of performance data at high temperatures.
- Lack of contacts with industrial companies with expertise in zeolites (e.g. UOP).
- Needs to be evaluated in a specific application.

Specific recommendations and additions or deletions to the work scope

- Need to step up testing.
- Focus on real-world operations and simulate systems performance.
- Continuously evaluate suitability of selected materials.

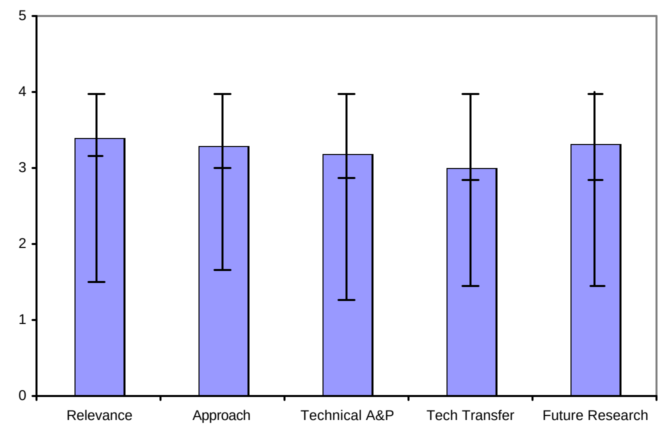
- Electron microscopy in cross-section; use focused ion beam-based extraction methods to produce TEM images of the through-thickness architecture.
- Consider expanding tests to include higher pressures.
- The fundamental aspects of zeolite membrane should be emphasized in this project to advance the know-how in film growth – e.g., role of substrate; variables control which leads to defect free film; trade-off between H_2 flux and selectivity; and collaboration with HPD-3 project?
- Consider adding a task to the project scope that would demonstrate costs and commercial viability.

Project # HPD-6: Autothermal Cyclic Reforming and H_2 Refueling System
Kumar, Ravi; GE Energy

<u>**Brief Summary of Project**</u>

GE Energy, Environmental Research Corporation and Praxair are designing, fabricating, and demonstrating a reliable and safe H_2 refueling system based on autothermal cycling reforming. This system will be capable of producing 40 kg/day of H_2, sufficient for the refueling of at least 1 bus or 8 cars daily. The project goal is < $3/kg of hydrogen for 900kg/day units projected for 100's of units per year.

Overall Project Score: 3.25



<u>**Question 1: Relevance to overall DOE objectives**</u>

This project earned a score of **3.40** for its relevance to DOE objectives.

- ACR concept opens up new means of lowering small scale SMRs.
- An important project demonstrating significant hydrogen production at the distributed production scale.
- This project addresses demonstration and validation of reforming technologies and provides a benchmark for cost.
- Promising approach for H_2 production.
- An optimized combination of ACR and PSA could offer cost advantages over the current technology.
- Appears ready for relatively near-term deployment, relative to other production technologies.
- A complete package for forecourt NG reforming.

<u>**Question 2: Approach to performing the research and development**</u>

This project was rated **3.30** on its approach.

- Barriers clearly known.
- Key elements of cost and reliability well underway to be improved.
- Based on subsystem hardware development and system integration followed by testing and validation.
- Focused on integration - can identify issues associated with system integration.
- Stability work good.
- High pressure reforming vs. compression decision?
- A flow sheet with temperature/pressure for each block would be helpful.
- Sound approach for the proposed work.
- Barriers not specifically discussed - difficult to assess how they are being handled. (Need for longer life catalyst discussed).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.20** based on accomplishments.

- Many current performance goals achieved.
- Future goals seem likely to be achieved.
- Significant progress moving toward hardware testing.
- Good engineering performance.
- Good validation of low pressure technology.
- Catalyst lifetime tests look good.
- Modeling for high pressure proceeding well.
- Good integration of GE ACR technology with novel filling method, storage and dispenser.
- Need to confirm stable operations for a long time, continuous run.
- Uniqueness of ACR over conventional reformer was not adequately discussed.
- Integrated operations of all 3 steps (ACR & WGS & PSA) could pose challenges.
- Good progress on PSA and other downstream steps.
- Data presented were not accompanied by (a) pressure and (b) choice of catalysts.
- Seem to be on schedule and making good progress - no discussion of major breakthroughs.
- Very comprehensive evaluation of technology, including start/stop and turndown ratios (both very important for transit forecourt operations) and structural modeling.
- Identified some purification technical targets that are not being met; claimed that they expected to meet them without saying how.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Somewhat limited in coordination with the "user" community.
- Strong team exists but only limited external interaction.
- Would this project benefit from interaction with other DOE related projects?
- Seems to have a close interface between GE and Praxair.
- Good incorporation of Hydro-Pac and Praxair expertise.
- Integration of technologies from various manufacturers.
- Industry partnership exists.
- Good team arrangement.
- Needs expertise help in water gas shift step?
- Good collaboration but with a very limited number of partners.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Realistic project plan.
- Moving to system operation, testing and evaluation.
- High pressure prototype designed and under fabrication.
- Working with ASME to develop new standards for H_2 storage tanks.
- Project on schedule for successful completion.
- Good future work plan.
- Future research seems to focus on process optimization/improvement and increased operating life.

Strengths and weaknesses

Strengths

- Good demonstrated sulfur tolerance.
- A very complex project that is well managed.
- This approach will be important for near-term hydrogen production from natural gas.
- Involves significant industry cost share.
- Performance levels achieved (30 hour continuous operation, 30 start-stop cycles, <0.5% CO from shifts reactor).
- Novel reforming approach with good integration into fueling solution.
- A very interesting process concept which utilizes the expertise of GE and Praxair.
- Innovative, complete forecourt package.

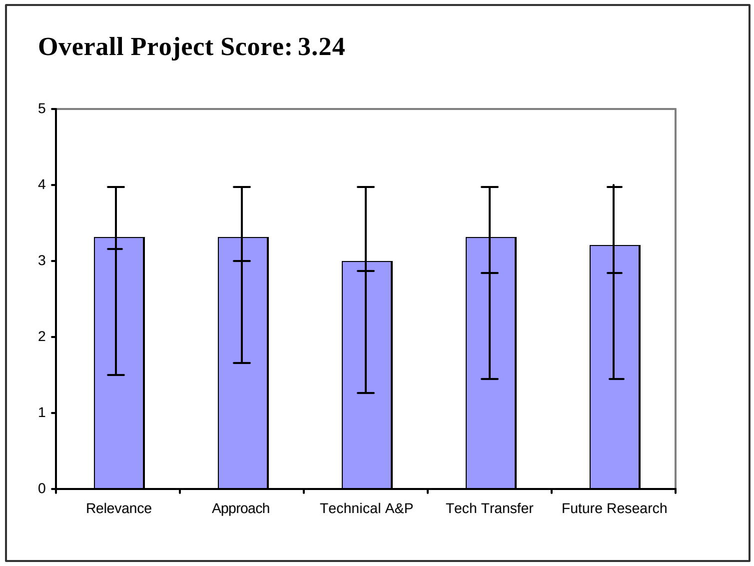
Weaknesses

- Need more time on testing.
- What is the lifetime of the catalyst?
- Final work done now is important, but not quite as novel as development and extension of ACR concept itself.
- Lack of outlines for the proposed operation of integrated system.
- A conceptual discussion would be helpful, e.g., how extensive is the integrated system operation?
- Did not explain in great depth elements being measured in this review.

Specific recommendations and additions or deletions to the work scope

- Explore opportunities for utilizing universities in this project.
- Consider expanding future work to consider higher (15,000-20,000 psi) pressures.
- Performance goal and detailed operation plan needs to be worked out (e.g., startup test duration), extent of integrated operations.

Project # HPD-7: Development of Supports and Membranes for Hydrogen Separation
Armstrong, Tim; Oak Ridge National Laboratory



Brief Summary of Project

This Oak Ridge National Laboratory (ORNL) project will (1) develop porous metal supports for hydrogen separation membranes that are compatible with the supported membrane and operational environment using a flexible fabrication process, and (2) develop thermodynamically stable, high temperature, high proton flux proton transport membranes (PTM) using a computational combinatorial chemistry approach. The latter will expand the computational model under development at ORNL that will allow the materials properties to be predicted based on the electronic properties of the elements of the periodic table.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Innovative work.
- Separation technology is important to hydrogen production goals and objectives.
- Both the substrate and the proton transport membrane aspects of the project are relevant to reducing costs and increasing efficiency.
- Needs to show more progress towards performance targets.
- Consider providing estimated costs at present, any barriers to meeting cost target, and if necessary, roadmap to address costs.
- Results from porous metal support tube development could yield benefits to membrane R&D.
- Purification of H_2 is essential to implementing H_2 economy using fuel cells.
- Potentially a useful component.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Team understands the barriers and goals.
- Ambitious approach given limited funding.
- Good materials science.
- Approach on porous metal support tube was sound.
- Proposed approach for proton transport membrane (PTM) is very wide in work scope.
- Very specific to address development of H_2 membranes, support tubes and proton transport membrane.
- Also has many go/no go points in Phase 1.
- A good plan.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Work has led to a possible new low temperature proton conductor.
- Significant progress based on minimal funding for this project.
- Progress against DOE targets not explained.
- Considerable progress was reported.
- Good progress for $200K.
- Is the water enhanced conductivity "durable" (i.e., does it persist with continued operation)?
- Some preliminary data were presented and looked promising.
- Little discussion of barriers. It appears, however that lots of progress has been made.
- Really neat work is being done.
- Good progress to date; still early though.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Coordination so far and future plans are comprehensive.
- Good interactions given the modest size of this effort.
- Good collaborations.
- Numerous collaborators (Ames Lab, WPI, NETL, Rutgers.)
- Consider more formal interactions and collaborations.
- Interactions with industry are needed to seek inputs and guidelines for the proposed work.
- Looking for partners to help commercialize and work with other labs and universities.
- Adequate collaboration to date; working on developing others should improve the work.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.22** for proposed future work.

- Go/no go considerations put early limits on whether to proceed on testing programs.
- Future work needs increased funding.
- Plan probably on target, but not well explained in relation to current progress.
- Hopefully they will continue to make progress with proton conducting membranes.
- A sound future work plan.
- Work is very focused and based on past progress.
- Good plan.

Strengths and weaknesses

Strengths
- Uses the strong materials development expertise at ORNL using existing technology at the lab.
- Good facilities and broad-based expertise in materials science; they are doing enough science to gain useful insights about ion conduction in solids.
- PI has expertise in porous metal supports.
- Really interesting project - seems to be making good progress.

- Getting a good understanding of the fundamentals.

Weaknesses

- Timeline to commercialization seems to be much longer than needed.
- The current status of the project in reaching the targets was not shown.
- Based on the efforts so far, it is uncertain how much progress has been made toward reaching the flux, cost, and purity goals.
- It is not easy to orchestrate a well-paced program of this kind at a National Laboratory for $200K.
- For proposed work on porous metal support PTMs , it would be helpful to differentiate the proposed work from the past/ongoing work by other researchers.
- Would have been better if they discussed barriers and explained better how/why innovations are so innovative.
- Will need to bring in others to move technology forward at the appropriate time (not yet).

Specific recommendations and additions or deletions to the work scope

- It is not clear that this project is funded at a "critical mass" level. Funding should be increased or project combined with other efforts.
- Project presently looks at high temperature operations -- confirm that materials chosen can operate successfully under lower temperature conditions and applicable operating pressures: e.g., start at -50F or establish lower temperature limits often called critical exposure temperature (CET).
- Place a higher priority for porous metal support tube development which could have broader and near-term applications than PTM.

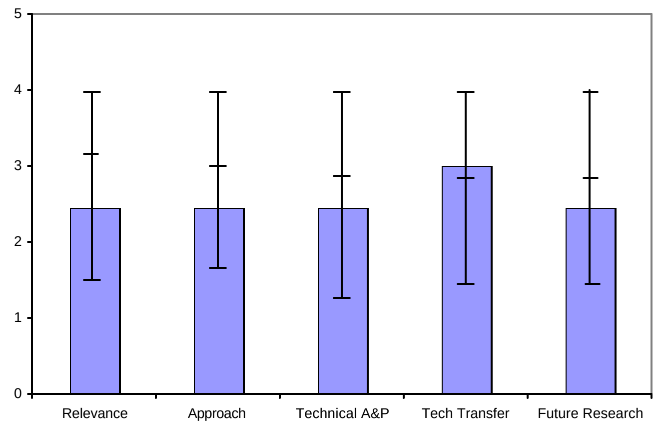
Project # HPD-8: Adapting Planar Solid Oxide Fuel Cells for Use with Solid Fuel Sources in the Production of Distributed Power

Bayless, David; Ohio University

Brief Summary of Project

In this project, Ohio University will quantify impacts of syngas composition on performance of a commercial planar solid oxide fuel cell (pSOFC) cell and stack (H_2S content, CO/H_2 ratio and energy content of gas, particulate, metal content), demonstrate long term operation of pSOFCs using actual sold fuel-derived syngas, integrate CHP into distributed H_2 production, develop fuel cell CHP from solid fuels, test pSOFCs for tolerance to syngas contaminants using single cell and stack platforms, and use CO tolerant pSOFCs for H_2/CO separation without gas shift reactors.

Overall Project Score: 2.55



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.44** for its relevance to DOE objectives.

- The use of a renewable energy source such as biomass is positive but issues such as contaminants and GHG emissions must be considered.
- Project addresses stationary and transportation applications of syngas derived H_2.
- H_2 for transportation is a by-product. Does not address biomass gasification targets such as H_2 cost.
- DOE also supports separate work on SOFC development.
- It is not clear how the proposed work would complement the ongoing SOFC program.
- Relevance not clearly established but is important for near-term implementation of H_2 economy.
- When evaluated as a Hydrogen Production Technology project it is not clear how this would be a significant advancement.

Question 2: Approach to performing the research and development

This project was rated **2.44** on its approach.

- Appears to duplicate FE work.
- Very complicated concept with little understanding of many barriers.
- No actual technical details given to support approach.
- No information given on how cost and durability factors will be assessed.
- Fuel flexible (syngas).
- Will require work on carbon sequestration, which is out of HFCIT preview.
- Fuel cell work is out of scope of hydrogen production subsystem.
- Not focused on reducing cost of hydrogen or meeting H_2 production objectives.
- This is basically the same as H_2 from coal.

- Details of the approach were lacking (e.g., the SOFC test duration and baseline case - feed gas composition, temperature and pressure).
- Considerable efforts will be spent on the gasifier and syngas H_2/CO ratio adjustment.
- Not being familiar with this project, it is unclear exactly what they are testing.
- In general, this work seems relatively well focused.
- How are economics calculated?
- Seems to be only economical if H_2 is co-produced!
- Appropriate for what they are planning to do.

<u>Question 3: Technical accomplishments and progress toward project and DOE goals</u>

This project was rated **2.44** based on accomplishments.

- Some degree of testing done. Should have been initiated at SOFC to bridge the setup time at OU.
- No performance indicators of the specific process or costs.
- Little progress for a large budget project.
- Testing has just begun.
- Need to show directly how the efforts contribute to achievement of the technical targets.
- Making some progress with modeling effort.
- Progress was reported but lacks details.
- Progress seems significant and some barriers are identified.
- Seems that there has been significant progress on experimental setup and modeling.
- Making progress within defined scope.

<u>Question 4: Technology transfer/collaborations with industry, universities and other laboratories</u>

This project was rated **3.00** for technology transfer and collaboration.

- What are partners' roles?
- Mentions many partnerships but no discussion of their role.
- It's not clear that interactions have benefited projects to date.
- Academic partners, industrial partners, and power company involved.
- Partnering with Case Western.
- Should try to work with DOE SOFC development team members.
- Should seek partnership with experience in gasifier and syngas clean up.
- Quite a bit of collaboration with universities and industry.
- Degree of that collaboration unclear.
- Several collaborators listed, but little identification of their roles.

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **2.44** for proposed future work.

- SOFC has performance issues with their stack operating on CH_4.
- Wouldn't single cell tests on H_2S, Hg be beneficial?
- Plans generalized.
- Little detail regarding future plans.
- The future plans do not address the hydrogen production targets sufficiently.

- The fuel cell work is not applicable in the H_2 production sub-program of DOE and does not address costs of H_2 directly.
- Schedule of proposed future work was presented.
- Future work sounds like it focuses on lowering cost and improving system (moving towards commercialization).
- Appropriate for what they are trying to do.

<u>Strengths and weaknesses</u>

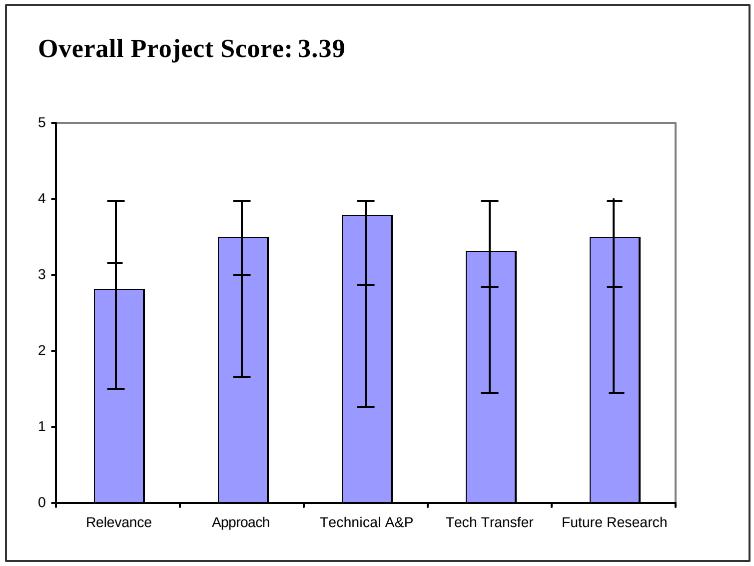
<u>Strengths</u>
- Good application of SOFCs.
- Good test facility established.
- Leveraged with funds from the State of Ohio.
- Use of CO tolerant SOFCs.
- Use of solid fuel which is easily and safely transported.
- Work to study the impact of syngas composition including trace contaminants on SOFC performance.
- Should provide valuable inputs to guide coal-based SOFC applications.
- Seems to be making really good progress.

<u>Weaknesses</u>
- All the test stands exist at SOFC -- why didn't testing start earlier using their facilities?
- Significant funding for little results.
- No attention given to problem of CO_2 emissions from syngas generation of biomass.
- Project does not address the fundamental work that needs to be done to reduce H_2 costs.
- The project is focused on a single system.
- Title of work is "Adapting Planar SOFC for use with…". What does "adapting" mean?
- Focus of the efforts should be clarified: SOFC or both SOFC and gasifier?
- Not sure electricity production as the primary product is in keeping with program intent.
- The use of sequestration was not clear.
- When evaluated as a Hydrogen Production Technology project, it is not clear what the advantage is.
- Mainly appears to eliminate WGS by adding a SOFC; is this a good thing?

<u>Specific recommendations and additions or deletions to the work scope</u>

- Look at other impurities in coal gas - Sb, P, etc.
- There are lots of heavy metals in gas stream.
- To this reviewer's knowledge no one has looked at heavy metal effects on SOFC performance.
- Delete H_2 distribution -- make project a fuel cell project CO + H_2 to a SOFC.
- This project seeks to "reinvent the wheel" in terms of biomass technology that has been previously explored.
- Focus work on specific system aspects that can have the greatest impact on achieving DOE targets. Considering system integration issues but not limiting applicability to a single system.
- For materials of construction, consider confirming operation capability under cold, e.g., -50 F temperatures.

Project # HPD-9: Maximizing Photosynthetic Efficiencies and Hydrogen Production in Microalgal Cultures
Melis, Tasios; University of California, Berkeley



Brief Summary of Project

In order to maximize photosynthetic efficiencies and H_2 production in Microalgal cultures, the University of California, Berkeley developed genetically engineered microalgae with enhanced photosynthetic solar conversion efficiencies and biomass/hydrogen production capabilities under mass culture conditions. The adopted approach was to apply DNA insertional mutagenesis and screening in the model green alga *Chlamydomonas reinhardtii* for the isolation of 'truncated Chl antenna' transformants and apply biochemical, genetic and molecular analyses of the transformant cells, followed by DNA sequencing to identify genes that confer a 'truncated Chl antenna size'.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.83** for its relevance to DOE objectives.

- Addresses only one barrier but focus is tight.
- Will help both efficiency and reactor design.
- Difficult to see direct relationship to overall DOE objectives.
- Not critical to Fuel Initiative but a potential long-term sustainable source of H_2.
- Ultimately, the success of this work could contribute substantially to the DOE H_2 program vision.
- Probably always behind in reaching a useable technology.

Question 2: Approach to performing the research and development

This project was rated **3.50** on its approach.

- Tightly focused on one critical barrier.
- Project is focused on overcoming barriers.
- Genetic manipulation is a cutting edge approach. Though high risk, it has potential for major breakthroughs with unforeseeable consequences/benefits.
- Good application of insertional mutagenesis.
- The presentation focused only on reducing the light capturing antennae size; the total approach for H_2 production was not conveyed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.80** based on accomplishments.

- Surpassed goal.
- Small project.
- Exceeded 2004 goal - doubled it!
- Improved photon penetration.
- Mechanism(s) of gene function in H_2 production still unknown.
- Excellent bio-engineering research toward producing more efficient light capturing mutant organisms. No assays for H_2.
- Will the greater (now 15%) light gathering efficiency actually translate into a corresponding enhancement in H_2 production?
- Ahead of schedule!

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Collaborations good with other photobiological EERE- H_2 projects.
- Premature for tech transfer.
- Extensive collaboration with peers doing related research.
- Good interactions with labs.
- Positive interaction with auto industry participant.
- Could benefit with bioinformatics and/ or genetic research companies.
- NREL and ORNL collaborate.
- Critical collaboration with NREL.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.50** for proposed future work.

- Good but would reemphasize "future work slide" task 4.
- For target goal - task 1 future is less important - "understanding" is targeted goal achieved by random screen approach.
- PI discussed need to test task 2 in order to have methods that may extend impact on regulation to other algae.
- Project goal is well defined.
- Logical plan for follow-on research.
- They have a ways to go to reach the production targets of other methods.

Strengths and weaknesses

Strengths
- Focus.
- Random approach with strong screen.
- Basic research being done; i.e., exploratory research methods.
- Knowledgeable PI.
- Effective collaborations.

Weaknesses

- Concern on how easy to extend to additional algae beyond *Chlamydomonas*
- Concern on GMO - something better than antibiotic for large scale use.
- Managing oxygen and achieving sustained H_2 production.

Specific recommendations and additions or deletions to the work scope

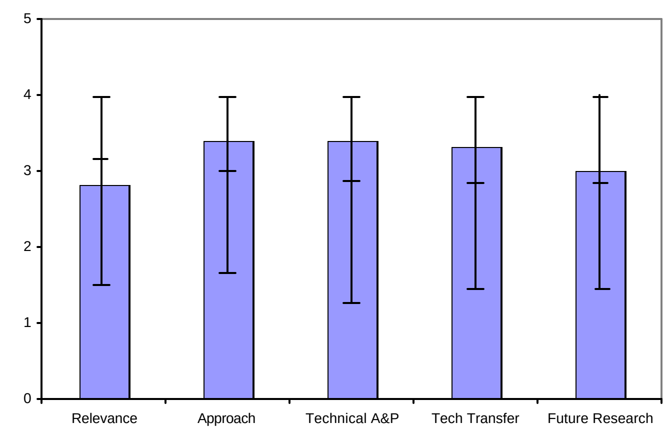
- If not already being done, systems analysis and engineering should be included in the project to determine whether the ultimate success of the project will lead to meeting DOE H_2 production goals of being competitive with gasoline.
- PI is very goal-oriented and should be "team leader" for all of the photobiological hydrogen work because he has shown the most progress. He is also most organized with his approach of all those working on photobiological hydrogen production.
- Combine the four separate mutations as highest priority.
- Consider second row of mutation and screen on best mutant "tlaX."
- Need to more closely relate algae types, mutant with H_2 photosynthesis, H_2 as well as O_2 production.

Project # HPD-10: Biological Systems for Hydrogen Photoproduction
Ghirardi, Maria; National Renewable Energy Laboratory

<u>**Brief Summary of Project**</u>

The goal of this project is to develop hydrogen production technologies based on microbial water-splitting processes. The project is organized into three tasks: 1) engineer an algal hydrogenase that is resistant to oxygen inactivation; 2) develop and optimize a physiological method to produce culture anaerobiosis and subsequent H_2 production activity in algae; and 3) introduce bacterial hydrogenase with increased oxygen resistance into a water-splitting photosynthetic cyanobacterial system.

Overall Project Score: 3.19



<u>**Question 1: Relevance to overall DOE objectives**</u>

This project earned a score of **2.83** for its relevance to DOE objectives.

- One barrier addressed continuous production.
- Difficult to relate project to overall DOE objectives.
- The long-term aspect of the work means it is not critical to the President's H_2 Initiative, but is relevant to the long-term vision of DOE.
- Methodology is still along way from practicality.
- Cleary a very long term project which should at present be nearer a basic science endeavor.
- Relevant, but progress has been extremely slow.

<u>**Question 2: Approach to performing the research and development**</u>

This project was rated **3.40** on its approach.

- Staged reactors, nutrient limitation, and immobilized test to decouple growth, light, and H_2 production are good methods.
- The multiple sub-tasks were disconnected in the presentation - either focus or better indicate crucial integration.
- Just trying new things, or has prior approach reached a limit?
- Good bioscience.
- Integration with fiberglass support is a novel idea.

<u>**Question 3: Technical accomplishments and progress toward project and DOE goals**</u>

This project was rated **3.40** based on accomplishments.

- Great results in subtask 2 moderated by other subtasks.
- Long term photobio is an achievement.

- Success in subtask 1 on methods in protein expression of hydrogenase.
- Reduced volume and improved H_2 production.
- Achieved continuity of H_2 production.
- Improved O_2 resistance.
- Significant results and progress directed toward achievement of targets.
- Continuous H_2 production for 6 months with two-stage process.
- Impressive progress on subtasks 1 to 3.
- Might it be possible to utilize a synthetic analog of hydrogenases to perform the $e- + H+ <- -> H_2$ reaction; even in the presence of O_2?
- Much work but thus far little hydrogen produced.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- This is long term so perhaps tech transfer is premature criteria.
- Apparent extensive effective collaborations with others.
- Good collaboration with university - work seems to be complementary.
- International collaboration is positive.
- More interactions with genetic companies may be useful.
- Collaboration with ORNL, UCB, U of IL, and former Soviet Union.
- Excellent collaborations ranging from computational modeling to "bioengineering."
- If the approach works then O_2 may be an issue.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Subtask 2 process is strong.
- Subtask 1 is very basic but crucial for future bio-inspired approach.
- Subtask 3 is important to extend to other species, but is hydrogenase knock-out the first best step?
- Starting to look at ferrdoxin mediated processes.
- Continuation of excellent scientific work.
- Performing economic analysis at this present early science stage will have little value.
- A quantitative definition of process goals should be helpful.

Strengths and weaknesses

Strengths
- Success in subtask 1- hydrogenase expression shows strong value of mutual EERE and Office of Science support of different tasks. This is a credit to the principal investigators.
- Leverage by an Office of Science Program.

Weaknesses
- Disjointed in three subtasks.
- Need to track; explain better energy: light, carbon reserves, nutrients between multistage, cycle systems, etc.
- The PIs understands parts of the balance. This would make project more "sensible" to "engineers" and hard scientists.

- Presentation was a bit unclear.
- How to avoid O_2 induced deactivation?

Specific recommendations and additions or deletions to the work scope

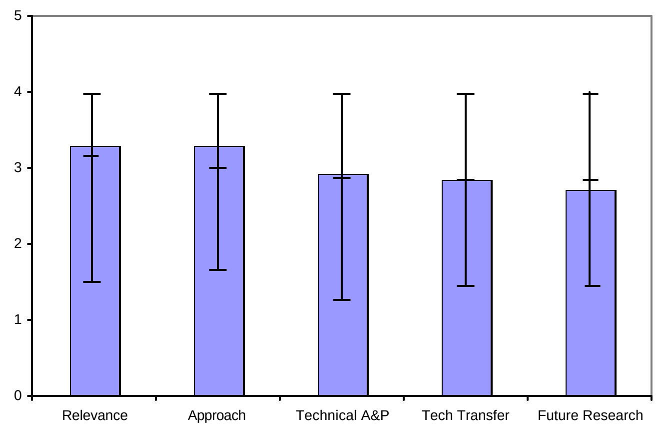
- An economic analysis would be an appropriate next step.
- Further integration with other DOE projects will be of great benefit (appears already to be a strength of the project).
- This work solidly addresses a major issue arising from photobiological hydrogen production and addresses a way to circumvent the problem but progress has been slow.
- The PI should be encouraged to take a far more active leadership role in this project.
- All photobiological projects should be combined under one team.

Project # HPD-11: Photoelectrochemical Water Splitting
Turner, John; National Renewable Energy Laboratory

Brief Summary of Project

The goal of this research is to develop a stable, cost effective, photoelectrochemical-based system to split water using sunlight as the only energy input. The work during this year focused on identifying and characterizing new semi-conductor materials that have appropriate bandgaps and are stable in aqueous solutions.

Overall Project Score: 3.01



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.29** for its relevance to DOE objectives.

- Addresses durability and efficiency targets and points out another important goal: band edge alignment with H_2O redox potentials.
- Photovoltaics in general is "limping" towards achieving any practical performance targets.
- Supportive in the terms of providing a means of generating H_2 by a sustainable source.
- Addresses a specific area within production that needs research.

Question 2: Approach to performing the research and development

This project was rated **3.29** on its approach.

- Excellent understanding of underlying scientific issues and use of this knowledge to develop improved materials.
- Good focus not only on demonstration of improved materials but also on consistent preparation of them.
- Concentrates on one candidate material at a time.
- What's new with this approach?
- The record for new semi conductor materials is important. But it somehow needs to be "catalyzed," made more convergent. For example by utilizing computational modeling.
- PI is staying focused on specific material performance issues and is addressing issues.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.92** based on accomplishments.

- Preliminary GaPN results are very promising for meeting band gap target.
- Progress on consistent materials preparation reported.
- Some progress with GaPn.
- Appears to be funding limited.
- Reasonable progress toward new semiconductor materials.

- The electrolytic conversion problem should be more efficiently addressed by considering the potential chemistry between the semiconductor components and the electrolyte.
- Progress is being made in finding stable materials for photoelectrochemical systems.

<u>Question 4: Technology transfer/collaborations with industry, universities and other laboratories</u>

This project was rated **2.86** for technology transfer and collaboration.

- Students from CSM and U. of Colorado involved in project.
- Collaboration with Mexico and other countries.
- Other than students, impact of these collaborations on this project not clear.
- Define role of collaborators.
- Where are more US collaborators?
- Clearly working closely with others in the field.
- Collaborations with U. of CO and Colorado School of Mines.
- Not well explained.
- Do they exist?

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **2.71** for proposed future work.

- Clear endpoint for completion of materials development and collaboration and transition to systems demonstration in FY 06.
- Requires more defined specifics.
- The key phrase here is "reasonable time frames."
- Project needs computational chemistry guidance, a better understanding of degradative semiconductor electrode/electrolyte chemistry.
- Appears to be well planned and structured.

<u>Strengths and weaknesses</u>

<u>Strengths</u>
- Excellent understanding of scientific challenges and approaches to overcoming them to meet PEC goals.
- Good progress.
- Enthusiastic, well-versed in topic.
- I imagine that the student researchers are well motivated by the PI.

<u>Weaknesses</u>
- Despite lack of funding for catalyst development, should be aware of any progress that could impact their ultimate goal of a system demo.
- Other important issues such as electrode development are missing.
- Need to develop collaborations in this area.
- Need more focused goals -- this is a never-ending project.
- Long way to go to commercial success.
- Funding. Very encouraging but needs 10X or 100X more funding to achieve objectives that are meaningful on a National scale.
- The present splintered format of a half dozen small projects in this area isn't working.

Specific recommendations and additions or deletions to the work scope

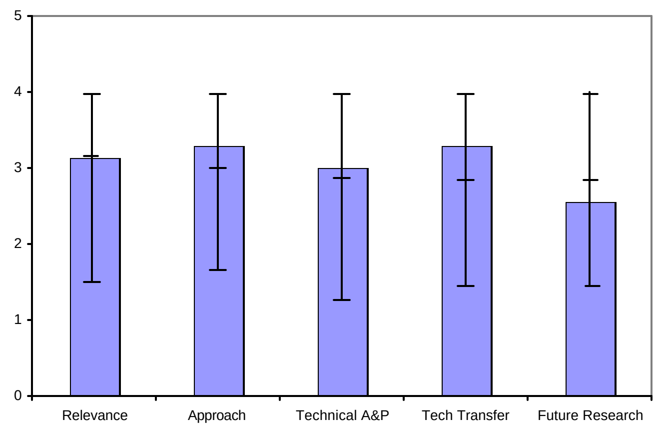
- The use of combinatorial methods should speed development.
- If EERE has a serious interest in developing photoelectrochemical systems, it should put in place a dedicated, multi-disciplinary program that is well-organized, well-integrated, and centrally directed.
- Recommend a collaboration with computational groups (not necessarily only at NREL) which could provide guidance on the search for more effective semiconductor.
- Recommend the addition of an industry partner even at this early stage to help set goals and objectives and define a product configuration.

Project # HPD-12: Photoelectrochemical Hydrogen Production Program
Miller, Eric; Hawaii Natural Energy Institute

Brief Summary of Project

In this project, Hawaii Natural Energy Institute (HNEI) is developing high efficiency, cost-effective photoelectrochemical processes for the production of hydrogen by engineering stable multi-junction photoelectrodes based on low-cost materials and designing, fabricating and testing optimized photoelectrodes suitable for eventual commercial-scale use.

Overall Project Score: 3.06



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.14** for its relevance to DOE objectives.

- Addresses durability target, but estimates for achieving cost target not yet available.
- Within National interest, clearly.
- Not very close to useful target values for production.
- Alignment in terms of potentially providing H_2 with a sustainable source.
- Addresses several objectives; materials, low cost, efficiency, and collaboration.

Question 2: Approach to performing the research and development

This project was rated **3.29** on its approach.

- Multifunction approach promising to overcome challenges by separating functions between the layers and enabling more focused development on individual targets for each layer.
- Dual materials approach to improve WO_3 and Fe_2O_3 is good.
- Like approach.
- Using standard approaches to band gap engineering.
- Combinatorial and *ab initio* features are useful.
- The advantage of the hybrid photoelectrode vis-à-vis alternative designs could have been better articulated.
- Strong focused approach taken on development of hybrid photoelectrodes.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Progress on Fe_2O_3 development but still a lot of challenges in this area.
- Doping mentioned as a solution - but what are proposed dopants?
- Proof of concept hybrid device demonstrated.
- Seems to have assembled good team of collaborators to accelerate progress.

- While accomplishments are being made, do not see the significant improvements needed to meet 2010 goals.
- Moving along well.
- Wait and see where they are a year from now.
- Good progress on doped WO_3 and Fe_2O_3 electrodes. But no data was provided on the lifetime of these new systems.
- Steady progress up through proof of concept has been achieved.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.29** for technology transfer and collaboration.

- They have a team of industry and university partners working with them.
- Will be interesting to see if sufficient level of expertise is now available to accelerate development beyond the exploratory WO_3 and Fe_2O_3 pure and doped samples prepared so far.
- Improved from past years.
- Strong point.
- Lots of collaborations are being formed, i.e., the so called "PEC Dream Team."
- Project is pulling together a "dream team" of collaborators which offer great promise.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.57** for proposed future work.

- Incorporates Intematix for combinational expertise and SWRI for manufacturability but planned technical work only touched on.
- A clearer plan for the next year with some intermediate goals should be developed.
- Future work lacking details.
- The project is clearly still at a "discovery" stage with significant hurdles (e.g., electrode longevity) to be yet determined.
- It seems premature to at this time to be considering a development plan towards commercialization.
- Timeline for goals is not evident.

Strengths and weaknesses

Strengths
- Good detailed approach - focusing on metal oxide materials development.
- Good discussion of the progress to date.
- Hybrid approach seems to have good likelihood of becoming a product.

Weaknesses
- Development effort seems a bit slow for a 3 year old project.
- They should really pick up the intensity or there won't be time to demonstrate the durability goals.
- Too heavily focused on out of date metal oxide systems.
- I do not see road to improvements.
- Future work discusses commercialization. I do not see technology developments that are ready to be commercialized.
- Little explanation of goals/timeline.
- Need to ensure that appropriate goals exist and are being pursued in a timely manner.

- Funding -- only a modest amount expended to date and no 2004 funds.
- The collaboration plan could unfold into a stronger, broad based, more concrete effort to nail down the answers to advancement issues for PEC H_2 production.

Specific recommendations and additions or deletions to the work scope

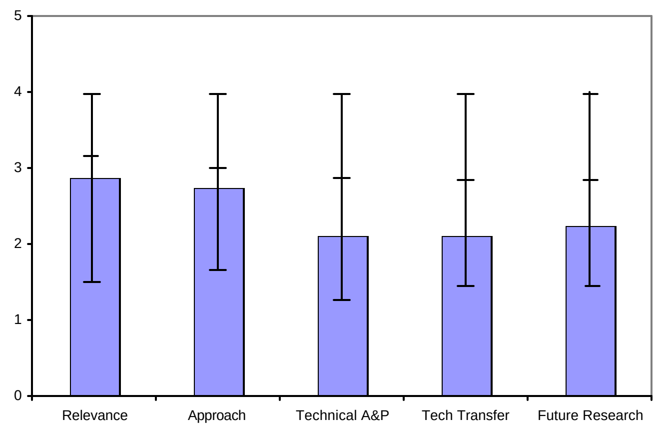
- Need to shift focus to new metal oxide systems.
- Integrate combinatorial approaches to development of metal oxides.

Project # HPD-13: Discovery of Photocatalysts for Hydrogen Production
MacQueen, Brent; SRI International

Brief Summary of Project

This SRI International, NanoGram Corporation, and Neophotonics project addresses efficiency (band gap and edges), durability and cost of photocatalyst materials for use in direct water-splitting systems for the production of hydrogen. The materials discovery required to meet the technical targets will be expedited by the use of high throughput screening tools being developed in this project. The inclusion of a partner with the means to produce commercially relevant amounts of materials will hasten the development required to make PEC hydrogen viable.

Overall Project Score: 2.42



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- Focus is on improving efficiency of existing durable oxide materials.
- Recognize need for order of magnitude improvement in durability.
- Primarily a materials development study.
- Not moving in on DOE's target values yet.
- Discovery of low cost materials with improved efficiency is critical to goal's realization.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- High throughput approach allows rapid materials screening.
- Industrial partner provides manufacturing/scale up expertise.
- Approach not well defined.
- Laser pyrolysis may lead to new materials development but impact on cost and durability remains to be proven.
- Impressive high throughput evaluation of semiconductor electrode materials - but only for the proton reduction to H_2 reactor.
- Semiconductor synthesis via nanoparticles "forming" into electrodes.
- Focus on high throughput analysis of new materials is outstanding.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.12** based on accomplishments.

- Variety of samples made and characterized but random materials classes pursued don't indicate a clear path forward.

- Progress is minimal.
- Do not see the path to meeting DOE's 2010 goals.
- Major delays in program.
- Difficulty in bringing all aspects of the planned project together.
- Project does not seem to be off to a productive start.
- Good first set of data but what does it teach us?
- Need a multidimensional database to relate H_2 evolution rates with material and other contributing factors.
- Business issues (multiplied) among partners is hampering optimal progress.
- Stay focused!

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.12** for technology transfer and collaboration.

- Existing interactions not focused on this application - no clear added value or impact.
- Need more coordinated interactions with other organizations.
- No significant collaborations with the exception of NanoGram (who apparently went into bankruptcy during project).
- Logistical issues.
- Weak on collaboration.
- Needs to publish and otherwise disseminate the excessive body of information that will emerge.
- Not yet evident that progress has been made from last year on collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.25** for proposed future work.

- Sounds like a lot of IP issues remain between SRI and NanoGram and based on Phase 1 and 2 delays these are not likely to be easily resolved.
- Future plans too broad and not based on prior results.
- Modeling aspect is good.
- Why is generation of database and modeling emphasized in phase 3 at the end of the project?
- Efficiency and catalyst lifetime need to be explored in a productive way.
- Ferroelectrics may open a door to improved performance.
- Consider ways to screen both electrode reactions (H_2 and O_2).
- Note that on CH_3OH oxidation product may interfere with the quantification of H_2.
- Develop ways to efficiently "mine" the large body of ensuing data for maximum progress towards project objectives.
- Benefit of doubt: Looks very promising.
- Need to stay focused and minimize external distracters.

Strengths and weaknesses

Strengths
- Very good technical capability is evident.

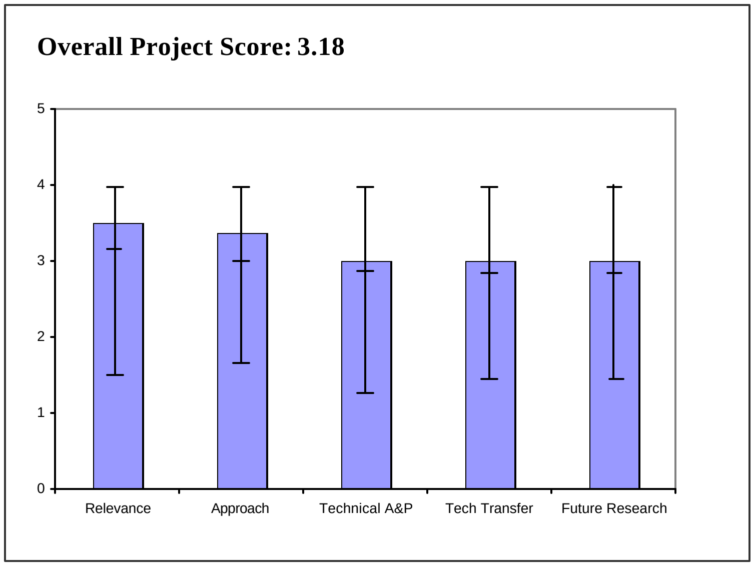
Weaknesses

- Can make and screen lots of materials but no effort to characterize some samples to understand why improvements or failures are achieved.
- Numerous delays are seriously impacting the likelihood this project can succeed in meeting DOE's goals.
- Modeling and materials developments need to be linked.
- The delays in this project have defeated the benefits of using a combinatorial methodology.
- It isn't clear that laser-based PY process will be cost effective.
- Again, external issues seem to be distracting from focus on production goals.
- Are legal issues a show stopper?

Specific recommendations and additions or deletions to the work scope

- End this project. Too many issues to succeed.
- The presenter needs to pace his presentation -- he ran out of time and did not adequately cover accomplishments and future plans.
- Too much emphasis on background tutorial -- this was not needed.
- A need for combinatorial development would improve development efforts.

Project # HPD-14: High Temperature Solid Oxide Electrolyzer System
Herring, Steve; Idaho National Engineering and Environmental Laboratory



Brief Summary of Project

Idaho National Engineering & Environmental Laboratory (INEEL) is currently researching and developing high and ultra-high temperature processes to produce hydrogen through chemical cycle-water splitting technology or other non-carbon-emitting technology utilizing heat from nuclear or solar sources. The project is seeking to develop energy-efficient, high-temperature, regenerative solid-oxide electrolyzer cells (SOECs) for hydrogen production from steam, reduce ohmic losses to improve energy efficiency, increase SOEC durability and sealing with regard to thermal cycles, minimize electrolyte thickness, improve material durability in a hydrogen/oxygen/steam environment, and develop and test integrated SOEC stacks operating in the electrolysis mode.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Very promising opportunity to overcome tech barriers in an important technology.
- This primarily is a high temperature materials development project.
- Excellent for stationary. Unclear for automobiles.
- Could meet several targets in a year or two at the rate they are going.
- Process is a key component of DOE's hydrogen production strategy.
- Production of pure H_2 without production of CO_2 in an energy efficient way.

Question 2: Approach to performing the research and development

This project was rated **3.38** on its approach.

- Very comprehensive understanding of tech issues.
- Straight-forward engineering development of cell technology incorporating high temp materials.
- Using nuclear heat and electrolysis (presumably from nuclear electricity) is what appears feasible for H_2 production in the near term.
- Research is actively addressing hard technical barriers.
- The project timeline is very aggressive given the current state of the art and small amount of initial funding i.e., single cells in 2004, 200 KW in 2008.
- Very focused in addressing technical barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Good progress this fiscal year.
- Project in early stages but shows promise.
- Progress seems slow- only single cell testing and 6-cell stack testing with significant performance degradation over short time period.
- Well done!
- Good H_2 production for >1000 hr.
- Significant progress is being made.
- Good progress - button cell tests, materials development, stack development and testing.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Interaction appropriate.
- Work with INERI in Canada just starting.
- This should be collaboration with SOFC electrolyzer manufacturers.
- It is basically a high temperature stack engineering project.
- Does Ceramatic meet this requirement?
- Partnering and information outreach could be more extensive.
- Excellent effort at sharing results and incorporating ideas from collaborators.
- Collaboration with industry, international and non-profit.
- University collaboration was unclear.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Future work not adequately described.
- Well thought out plan for the future.
- Little detail given on how project will move to 50 kW, 500 kW, and 5 mW.
- How will heat source be integrated into project?
- Future plans were not evident from presentation, with exception of testing of ten-cell stack.
- Future work scales up and improves upon past work.

Strengths and weaknesses

Strengths
- Uses the right kind of power source for near-term (and for the longer range for that matter).
- Adaptable to solar heat source as well.
- Aligns well with DOE stated goals.
- Very focused and making good progress.

Weaknesses
- Several organizations (companies) have demonstrated capabilities to make and test electrolyzers -- why are they not part of this project?
- NASA has funded development of electrolyzers at TMI (Cleveland, OH) for many years -- their expertise would be beneficial for this project.

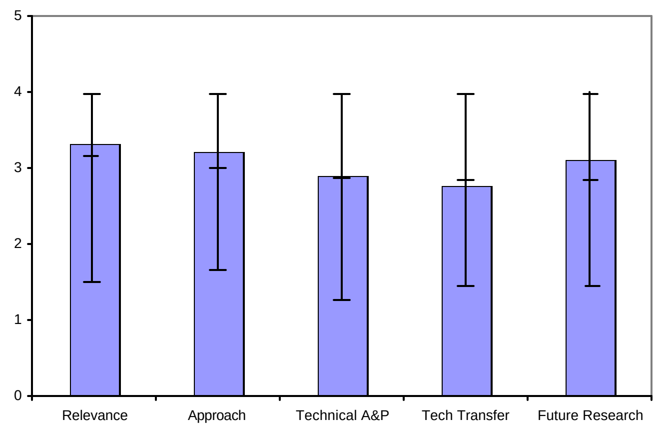
- Although the presentation "infers" a nuclear or solar heat source to produce high temperature steam, there appears to be little connection to these energy sources in future plans.
- Funding -- to develop from single coupons or short stacks to 200 KW prototypes with performance and durability will cost $25 to $100 million.

Specific recommendations and additions or deletions to the work scope

- This project should be led by industry with national lab providing high temperature materials expertise.
- Appears well done.
- A collaboration with NREL to develop the solar powered heat source concept appears appropriate.
- I assume the nuclear program will fuel extensive cell, cell stack and subsystem testing with emphasis on many pieces of hardware operating for significant hours prior to the buildup of prototype. If not this needs to be added.
- May need to consider some new/advanced ceramic materials for the electrolyte to achieve reductions in ohmic losses and to raise efficiency.

Project # HPD-15: Renewable Electrolysis Integrated System Development and Testing
Kroposki, Ben; National Renewable Energy Laboratory

Overall Project Score: 3.07



Brief Summary of Project

This National Renewable Energy Laboratory (NREL) project examines the issues with using renewable energy to produce hydrogen by electrolyzing water. Objectives are to characterize electrolyzer performance under variable input power conditions, test and evaluate the electrical interface with renewable (PV, Wind, Hydro, Geothermal, etc) and/or hybrid/grid power (dedicated hydrogen production, electricity/hydrogen cogenera -tion), design and develop shared power electronics packages and controllers to reduce cost and optimize system performance, develop and verify integrated renewable electrolysis systems (via performance modeling, simulation and testing; and addressing Safety, Codes and Standards requirements).

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Well designed approach.
- Good understanding of RD&D needs and project objectives.
- Emphasis on renewable energy sources to produce hydrogen.
- Linking renewables to provide output stabilization is a sensible focus.
- Incorporating renewables efficiently is vital to Hydrogen Initiative success.

Question 2: Approach to performing the research and development

This project was rated **3.22** on its approach.

- Doubt that improved electronics are going to get you to targets.
- They appear to be putting together known components - where are the potential breakthroughs?
- Power electronics RD&D is at the heart of this project, a key tech and cost barriers for electrolysis based systems.
- Good approach with detailed tasks based on realistic goals and objectives.
- NREL has the experience, facilities, and capabilities to make this work.
- Capital cost, efficiency, and durability are indeed the feasibility issues.
- Very structured, task oriented.
- Approach is addressing numerous barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.89** based on accomplishments.

- Maybe not fair to evaluate since early in project.
- Testing a known electrolyzer, known components.
- Collaborations need expanded - especially in power electronics.
- Project in early stages, but shows promise.
- Significant progress for a new project with reduced funding.
- Off to a good start.
- Steady rate of progress and accomplishments is evident.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.78** for technology transfer and collaboration.

- Project in early stage but interaction with appropriate collaborators off to a good start.
- Limited collaborations to date.
- There's value to having universities involved in such projects.
- Reasonable levels of industry and government collaboration are evident.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.11** for proposed future work.

- Evaluating all electrolyzer system (PEM/ Alkaline).
- Future work is "success" oriented, needs thought/planning on contingencies, other possible barriers needs timeline progress goals ($/kg).
- Good plans for future work in FY 04 and beyond.
- If they follow through effectively and productively this should turn out to be a good program.
- If energy source (e.g., wind) produces electricity for grid or electrolyzer, consider use of H_2 produced to run a fuel cell that places electricity (a less desirable option).
- Inefficient or confirm necessary to maintain net stand-by under turn down conditions.
- Clear plans for future work and goals are evident.

Strengths and weaknesses

Strengths
- Evaluating all electrolyzer systems (PEM/alkaline).
- Emphasis on achieving cost targets.
- Well thought out work.
- Leveraged with wind power funds.
- Very clear, precise presentation.
- Well organized, reflects a good project.
- Focused on the wind/solar power interface is very useful to the industry and often overlooked.

Weaknesses
- Doubt that they will be able to get from current >$13/kg to 2010 goal.
- The only indicated cost savings is some improved electronics and elimination of "battery ".
- Would have liked to see what goes into the current $13 cost and where the improvements will be made to reach the goal.
- Requires a storage battery to load level.

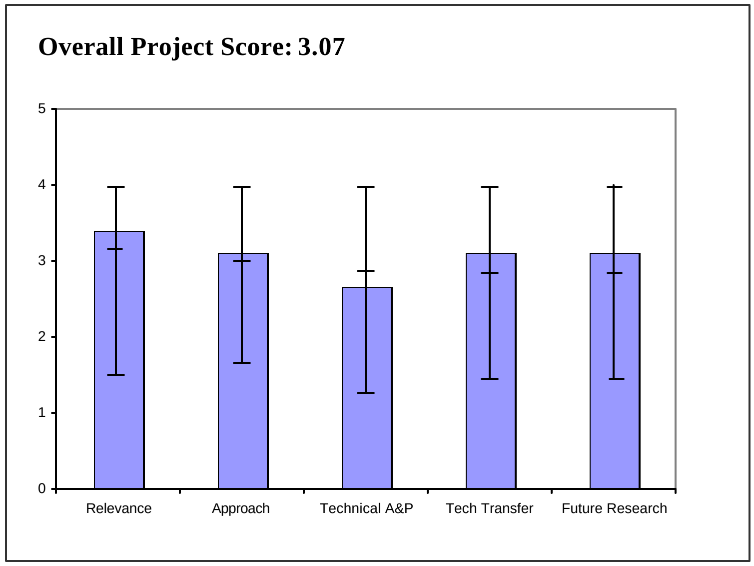
Specific recommendations and additions or deletions to the work scope

- Consider bringing biomass into the mix to provide the possibility of a load-leveled, all-renewable, battery-less process for making H_2.
- Need clarification of a technology/ intellectual property access plan.
- Other commercial organizations will want to use the power interface, and there should be a process to allow them to access this e.g. CRADA or others.
- Consider expanding scope to look at controls required to determine where initial energy, e.g., electric from wind, could be best utilized; direct to grid on for H_2 production - cost vs. revenue optimization.
- Need to study system optimization given intermittent operation of electrolyzer due to renewable energy duty cycle.

Project # HPD-16: Hydrogen Generation from Electrolysis
Cohen, Steve; TeledyneEnergy Systems Inc.

Brief Summary of Project

The goal of this Teledyne Energy Systems Inc. project is to advance water electrolysis technology and develop an Electrolytic Hydrogen Generator with the following features: hydrogen delivery at high-pressure (5,000 psig); relatively inexpensive hydrogen generation and pressurization; production capacity 10,000 scfd; high conversion efficiency; cost of less than $600/kW for 10,000 units per year; as well as reliability and durability with low maintenance cost.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.40** for its relevance to DOE objectives.

- Addressing efficiency and cost targets at both component and systems levels.
- Making use of some excellent experience.
- Addresses important potential technical advances for electrolysis production of hydrogen.
- Relevant performance goals as goals/objectives.
- Good description of specific targets which are challenging.
- Near term in scope.
- Will proposed system meet cost/performance targets?
- Project recently initiated (March 04) making evaluation of status premature.
- Supports water electrolysis technology in general terms.

Question 2: Approach to performing the research and development

This project was rated **3.10** on its approach.

- A long established piece of commercial equipment.
- Going to higher pressure probably a good move.
- Approach has some risk with use of high pressures but excellent potential to meet the targets.
- Some questions as to why is this being done.. Stuart Energy already has functional optimized system.
- Well designed.
- Barriers clearly understood as well as goals.
- Realistic, experimental-based approach.
- Close to off the shelf.
- Once again, barriers to be addressed were discussed in general terms.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.67** based on accomplishments.

- Too early to evaluate.
- New project, but extremely well thought out.
- Project in early stages but indicates substantial improvements to target.
- Project only 5 weeks old. Too early to expect results. Not realistic to rate this criteria.
- Not applicable.
- They seem to be on schedule for a new project.
- Looking forward to next year's progress review for this project.
- Project just starting.
- Not started yet.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.10** for technology transfer and collaboration.

- Collaborators provide relevant expertise to this program.
- Proposed interactions appear minimal at best.
- Appropriate involvement of related industry and state entity. (Demo site, public education/awareness).
- Good interactions - potential association with transit application is positive.
- Proposed interactions are appropriate.
- Most of the collaborations are parts/materials suppliers.
- Excellent collaboration efforts were described.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.10** for proposed future work.

- FY 04 work provides basis for systems design and trade studies.
- Would benefit from having FY 04 milestone for testing results to indicate go/no go on system development.
- No details outside of timeline provided.
- Project off to a good start and future expectations seem feasible.
- Reasonable plans - schedule should be accelerated if possible.
- Plan is to eventually build a "demonstration" system. Focus on optimizing electrolysis system.
- Plan is very well developed.

Strengths and weaknesses

Strengths
- Excellent understanding of issues at both component and systems level.
- Detailed analysis of efficiency and cost goals for project based on DOE targets.
- Trade-off studies for system optimization are important.
- Cost-pressure optimization is also positive.
- A company with lots of H-generation experience.
- 50% cost share by Teledyne.

- Strong industrial collaboration was evident.
- Experienced team developing and cost reducing a power technology.
- Good chance for success.

Weaknesses

- Appears to duplicate work at Stuart (questionable).
- Need to evaluate the cost impact of scaling production capacity to optimize unit costs.
- Liquid KOH at pressure is a challenge.

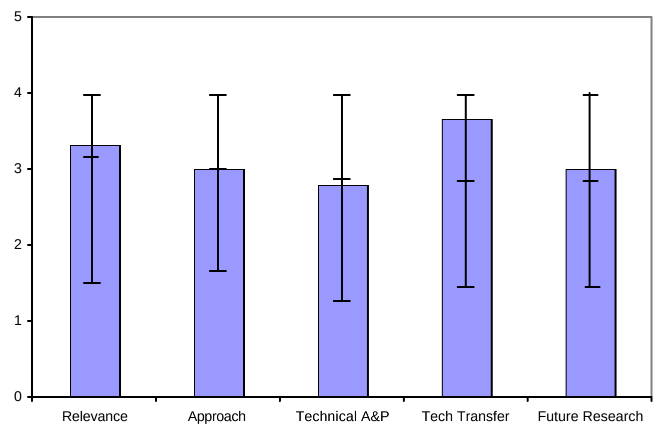
Specific recommendations and additions or deletions to the work scope

- Consider need to supply H_2 at 10,000+ psi based on expected need for fueling vehicles.
- Teledyne should try to take their H-gen systems to a new level with some "outside the box" developments.

Project # HPD-17: Development of Solar-Powered Thermo-Chemical Production of Hydrogen from Water
Schultz, Ken; University of Nevada

Brief Summary of Project

Overall Project Score: 3.16



The goal of this Solar Thermo-Chemical Hydrogen (STCH) team project is to define economically feasible concepts for solar-powered production of hydrogen from water. Task I objectives are to: screen and select cycles and systems; establish a thermochemical water-splitting cycle database; develop solar receiver/reactor design concepts for top cycles; and analyze and select the best systems for development. In Task II they will build on earlier CU/NREL work to study metal oxide reduction cycles, design an improved ultra-high temperature solar-thermal reactor, and conduct fundamental studies using CU transport tube reactor and the NREL High-Flux Solar Furnace.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Determining the potential for solar H_2 production is important.
- Relationship to overall DOE objectives was not described.
- This program has sufficient scope and resources to get a credible go/no go decision on solar-based thermochemical H_2 production from H_2O.
- Solar, high temperature thermochemical cycles support the initiative in all aspects- crucial for long term sustainability.
- Important work on a long term portion of the DOE technology portfolio.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- This appears to be a very high-cost paper study with only limited experimental effort using existing facilities on thermochemical cycles that have been previously studied.
- Roles/responsibilities of partners should be better identified.
- The relative cost of this project appears high for the results targeted.
- Approach doesn't seem to be consistent with lower cost solar collectors.
- Criteria based and the chosen 16 criteria are well thought out.
- Screening methodology is pretty consistent with the other methods of screening used for other programs.
- Good application from learning gained in the nuclear program.
- Addressing targeted barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.80** based on accomplishments.

- Only limited accomplishments in 7 months.
- Seems to be off to a good start.
- The database assessment will have great value in the community.
- Leveraging research done by other groups.
- Adequate progress considering newness of the project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.67** for technology transfer and collaboration.

- Various interactions noted.
- Clearly involving wide variety of resources and organizations.
- Lots of collaboration and well chosen interfaces.
- Good collaboration among variety of parties.
- Web site to show findings and good efforts to make progress as transparent as possible.
- Good leveraging of other programs.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Too much paper study not enough experimental verification of the potential for solar-produced hydrogen.
- Almost all work is future work.
- An impressive plan - stick with it.
- Aggressive schedule to meet DOE cost objective.
- Appropriate for program stage and objectives.

Strengths and weaknesses

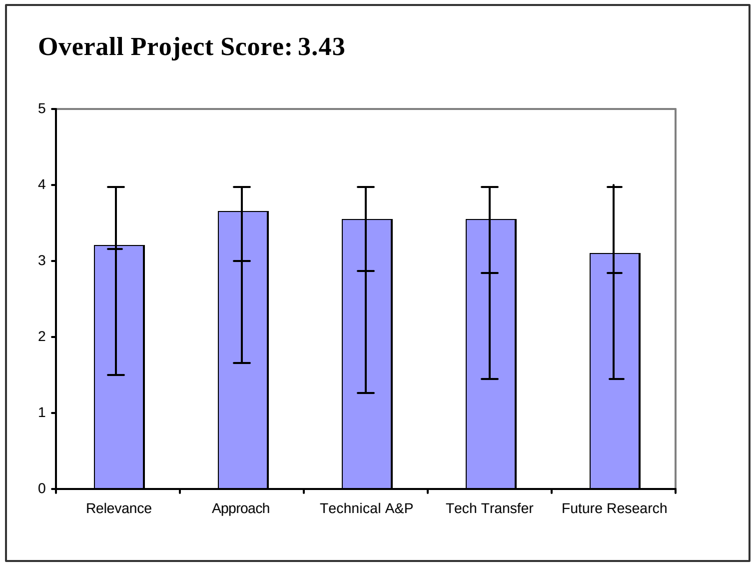
Strengths
- A strong capable team.
- Can lead to commercialization.
- Good presentation at review (strong spokesperson).
- Excellent methodology used to structure and rank research.
- Solar thermochemical is a very high potential production technique and this project should help to focus further/ future projects.
- Ambitious attempt at finding the optimal solution at this stage of the technology.
- Excellent collaboration.

Weaknesses
- Team is not challenged to come to grips with the critical feasibility issues of solar hydrogen production.
- Why do the analysis study if two cycles, ZnO and Mn_2O_3 have been chosen?
- Seems to not be terribly innovative (draws heavily on previous work).

Specific recommendations and additions or deletions to the work scope

- This team should be challenged to produce more important results/conclusions.
- Do a 3-month literature study and get started on an experimental verification project to assess value and cost competitiveness of solar, thermochemical hydrogen production.

Project # HPD-18: Moving Toward Consistent Analysis in the Hydrogen Program: H_2A
Mann, Maggie; National Renewable Energy Laboratory



Brief Summary of Project

The H_2A project team's overall goal in this project is to bring consistency and transparency to hydrogen analysis. Phase I goals include production and delivery analysis, consistent cost methodology and critical cost analyses, R&D portfolio analysis, and tool development for providing R&D direction.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.22** for its relevance to DOE objectives.

- Fits DOE Multiyear RD&D Plan goals.
- Tool will be available on DOE website for cash flow analysis-somewhat limited utility.
- Development and refining baseline analysis elements is a needed reference tool.
- Consistency is a critical need.
- Political and price scenarios should be explored.
- No clear relationship to overall DOE objectives shown, but clearly a useful tool to assist funding decisions.
- Scope of analysis impressive.
- Project is very important in identifying appropriate research directions.
- Consistent analysis basis will be beneficial.
- The core mission of this project is to provide consistency in cost/benefit analyses to determine if DOE goals, objectives and targets are met.
- Should provide a useful tool for apple vs. apple analysis.

Question 2: Approach to performing the research and development

This project was rated **3.67** on its approach.

- Appears to be a well thought through project.
- Good use of cash flow analysis tool.
- "Forecourt" was not defined until end of project review - should be defined upfront.
- Project "barriers" and goals clearly identified.
- Communication should be emphasized.
- Should publish guidelines for units and assumption statements.
- Good team building.
- Not perfect, but the plan does embrace issues and criteria effectively.
- It will evolve into a comprehensive analysis function that produces reliable results.
- Sound tools including cash flow analysis were proposed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.56** based on accomplishments.

- Good use of technical paper publication.
- Base case and sensitivity analysis has progressed well.
- Tool looks great -- should be mandatory for proposals.
- Needs price scenario selection.
- Great examples with type profiles by resource.
- Delivery should include solid storage and delivery of feed stock.
- Relatively new project that has made impressive studies so far.
- Good accomplishments so far.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.56** for technology transfer and collaboration.

- Universities are part of the H_2A team - could use a better effort with other university tech transfer (more diversity).
- Interactions and collaborations are comprehensive. Quite a team!
- Collaboration with energy economists and independents recommended.
- Team included wide range of interests.
- Good use of web.
- All appropriate groups of stakeholder appears to be represented.
- Project leverages stakeholders in analysis and makes project available to all.
- Sensibly chosen collaborators.
- Should look to add more collaborators to shore up deficiencies as they become obvious.
- The role of key industrial collaborators was not adequately discussed.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.12** for proposed future work.

- Will document assumptions.
- Future not clear (beyond 04).
- Should include DOE identified scenarios.
- Phase 2 is reported to be under discussion.
- H_2 delivery analysis should consult studies by industry (e.g., GM).
- Implementation of "peer-reviewed papers" was not discussed adequately.

Strengths and weaknesses

Strengths

- Good use of National Labs plus contractor; part of Multiyear RD&D Plan.
- Use of sensitivity analysis (chart) is good.
- Good cross section of team partners.
- Meets a critical need for consistency.
- Fine start with the spreadsheet tool -- should improve analysis of proposals.
- Results showing builds by production type very well done and very interesting.

- Clearly excellent, much needed tool.
- Seemingly well done.
- Practical methodology.
- Useful expression of results.
- This is the kind of work EERE should sponsor to assure that the R&D programs are appropriate.
- Very good effort to finally create a standard model.
- Good set of partners including industry.

Weaknesses
- Could use more scenario analysis (fuel costs).
- Does not address major price and political scenarios.
- Proposals will play out differently depending on scenario.
- Needs more support for units - the preference for standard industry units can not be ignored.
- Time value of results not clear.
- Sensitivity analysis cited but not clarified.
- This is much new jargon in the naming of things -- this should be clarified and minimized to avoid confusion and lack of appreciation concerning results.
- There's lots of room for oversight and neglect of key issues in this kind of analysis.
- Inclusion of a "conclusions" slide would be helpful.

Specific recommendations and additions or deletions to the work scope

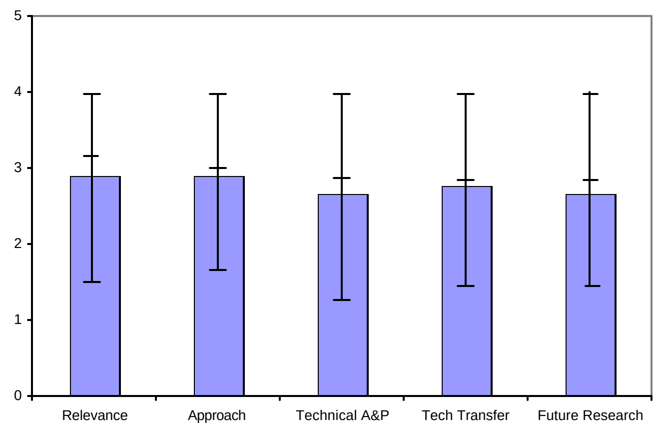
- Should look at / analyze safety for next piece, although safety was not an issue at this time.
- Develop consensus forecasts in major scenarios depicting different types of transitions, e.g. import reduction, fossil reduction, alternate energy breakthrough and maybe wild cards (global cooling, open global war, rapid growth, and depression).
- Include energy economist/ independent collaborators.
- Include both user preferred and program standard units e.g. both SCF and KG.
- An annotation on impact(s) would be helpful.
- Most important is to keep industry involved in identifying analysis needs and verifying models.
- Focus on usability/ transparency.
- Interface for other (non-economic) issues should be part of the project (i.e., WTW, emissions, etc.)
- Put all assumptions on the strongest possible grounding -- the results from this kind of analysis are often easy to criticize or take issue with.
- It would be nice to make the H_2A model user-friendly, if it is to be released for public use, for example, users should be allowed to pick its key parameters.
- Should be sure to widely disseminate along with providing training and support.
- Coordinating with education and outreach program will be beneficial if not already in place.

Project # HPD-19: Hydrogen Transition Modeling and Analysis: HYTRANS v. 1.0
Greene, David; Oak Ridge National Laboratory

Brief Summary of Project

This Oak Ridge National Laboratory (ORNL) team intends to rapidly create an integrated model of the transition to hydrogen as a transportation fuel using methods developed for the Transition Alternative Fuels and Vehicles (TAFV) Model. Objectives are: to produce a national-level model, HYTRANS v. 1; test HyTrans v. 1 and produce 2-3 scenarios of market evolution; produce a regional model; test and generate 2-3 regional transition scenarios; and publish model documentation and scenarios.

Overall Project Score: 2.78



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.89** for its relevance to DOE objectives.

- Driven by National Academies study.
- Version 1 is limited in scope.
- Safety is covered under ORNL research and safety guidelines.
- A much needed project.
- Addresses National Academies recommendation.
- Goals/objectives of project are relevant.
- Excellent idea for execution.
- Includes non-H_2 alternatives: hybrid and electric.
- Poor relevant effort.
- Mission expression was poor.
- An import issue is being addressed by this project, but the level of effort may be subcritical to cover all aspects thoroughly.
- Should provide useful guidelines.

Question 2: Approach to performing the research and development

This project was rated **2.89** on its approach.

- Non linear optimization model.
- "Barrier" elements well thought out.
- Approach seems reasonable but ability of model to yield sophisticated (not obvious) results is not clear.
- Optimization has limits.
- Intuitive, goal driven, and heuristic models should be considered as a supplement.
- Price scenario should be included.
- No clarity on origin of input data.

- Admitted doesn’t understand current pipelines.
- Needs to study all possible production technologies and must be designed for flexible response as new concepts emerge.

<u>Question 3: Technical accomplishments and progress toward project and DOE goals</u>

This project was rated **2.67** based on accomplishments.

- Lots of data! More observations than project's plan - could use more specifics on project itself.
- Project in early stage but good progress to date.
- To date the model results seem to "confirm the obvious."
- Most conclusions are evident to an informed observer without the model results.
- Impressive model structure and problem description.
- Claim that model "solves" chicken and egg question completely unsupported.
- Mathematical expressions confusing.
- Relatively new project; some results are starting to come out.
- Vehicle diversity and demand density concerns are valid targets for study.

<u>Question 4: Technology transfer/collaborations with industry, universities and other laboratories</u>

This project was rated **2.78** for technology transfer and collaboration.

- Did not hear this clearly expressed during presentation.
- Collaboration will need to spread to many other entities, e.g., industry.
- The planned advisory group and workshop should provide useful sophistication for the model.
- Economic, political, and independents should be involved.
- No clear communication intent.
- Some collaborations are in place; others may be needed to assure comprehensive coverage of all parameters.
- Discussions in this area were not adequate.

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **2.67** for proposed future work.

- Not specific enough.
- Very robust plan.
- Incorporating stationary demand and production is positive.
- Emphasis on "robust" solution is good.
- Survey work would be useful.
- FY 2004 and FY 2005 results at the next review should sharpen the evaluation of this approach to the point where its value can be better addressed.
- Schedule seems to be aggressive.

<u>Strengths and weaknesses</u>

<u>Strengths</u>

- Project seems to have uncovered other areas of research.
- Willingness to obtain external input/criticism for model improvement.

- Excellent idea.
- Nice application of mathematical optimization.
- Nice inclusion of competing technologies for current fleet inclusion.
- Very good start on a very complex problem.

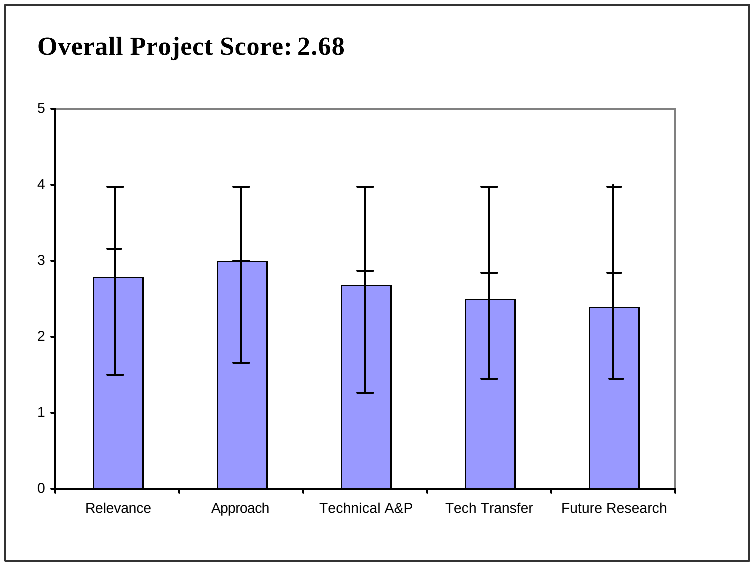
Weaknesses

- Chart with population density has no legend (US/green); not a lot of explanations "why" they did what they did.
- Without extensive model development in terms of sophistication, the results tend to be just confirmation of obvious conclusions.
- Optimization has inherent weaknesses -- particularly in the propensity to find ideal solutions.
- The transition will not be ideal -- will rather move forward with optimal steps.
- Possibility of future fleet of superlights/smarts, trucks, motorcycles, bicycles, and subways -- or even a revival of public transportation.
- Fails to justify money spent on project.
- This study brings some new jargon to the program. Be sure to clarify and define all such new terms at the next review.
- Would benefit from additional outside collaborations, e.g., Dept. of Defense, oil companies, investment banks, etc.

Specific recommendations and additions or deletions to the work scope

- PBFA is now called PBA should reflect change in slides.
- 2005 to 2050? Keep timeline within program plan.
- Incorporate as much sophistication into the model as possible.
- Explore use of suboptimal modeling -- goal driven, heuristic, and scenario modeling.
- Include economic, political, and independent collaboration.
- Surveying structuring may provide some useful insight.
- Cancel this effort.
- Theoretical models should be funded at low level to allow for corrections to the model.
- Heavy funding is not warranted until trends unfold in the marketplace.
- This project seems to have synergy with HPD-18 project.
- Should a formal bridge be built between the two projects?
- Interaction with industry and other government agencies (e.g., DOE) would be helpful.
- This tool could be vital for national security planning. Coordination with DOD threat analysis and scenario planning should be done; for example, given the inelasticity of prices small disruptions cause great volatility and uncertainty. Financial markets go to great lengths to hedge against volatility and place an economic value on this factor. Domestic H_2 may play a similar role.

Project # HPD-20: WinDS- H_2 Model and Analysis
Short, Walter; National Renewable Energy Laboratory



Brief Summary of Project

In this analysis project the National Renewable Energy Laboratory (NREL) will identify the scenarios, time frames and regions of the U.S. in which wind turbines that generate both electricity and hydrogen are likely to become economical from a market perspective. Objectives are to optimize wind system concepts that produce both electricity and hydrogen, both today and in the future.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.80** for its relevance to DOE objectives.

- Sounds like a good project - not sure how this project fits in with hydrogen! Primarily electricity production.
- Wind as renewable energy source is important.
- Hydrogen production by electrolysis is incidental to wind produced electricity.
- Hydrogen transport based on electrical distribution roots is not realistic - why not just produce H_2 at electrical distribution points.
- Wind shouldn't be done alone. Need to include solar, bio, and other non-fossil fuels electrolysis.
- Wind alone is not necessarily relevant.
- Clear expression of mission.
- Making a concentrated study of H_2 production from wind energy.
- The study is needed to put the prospects for wind utilization in proper perspective.
- Project recognizes unlikely use of electrolyzer and fuel cell at wind sites to store/shift energy.
- Allows resources to be refocused.
- A useful exercise.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Integrated with other work.
- No safety issues for this project.
- Hydrogen production/transport seems to be an "add on" to an existing wind model.
- It is not clear how this production model is based on where the wind is relevant to hydrogen production. It is just a wind produced - electricity methodology.
- Good comparison with other uses for wind, e.g., grid, local use, electrical storage systems.
- Lack of practicality checks.
- Reasonably well considered approach. The PI should endeavor to make the modeling/analysis as comprehensive in its consideration of the forcing issues as possible.

- Wind power production, future growth rate, and wind power subsidy: are these factors taken into consideration?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.70** based on accomplishments.

- No legend on "regions" slide.
- Just showed class 6 but project used 3-7- confusing to listener.
- Base case results slide should have wind "electric."
- New project evaluation "N/A" to some degree.
- Only limited results for almost a year of effort given wind model already existed.
- Cost/performance scenarios would have been more interesting if current status values were used in place of 2010 target values.
- Lessons can be applied to other intermittents.
- Excellent micro-modeling techniques might be useful in vehicle transition.
- Made deliverables - but didn't say to who or how used.
- Will get a better idea about the usefulness and credibility of this project at the next review.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Did not discuss this during presentation.
- Collaboration internal to NREL only.
- No interactions outside of DOE and NREL.
- Critique by industrial H_2 providers would have benefited early results.
- Needs to include other intermittent, source-related collaborations.
- No team building intent but seems necessary.
- No external collaborators.
- Some university in the USA must have a program of a closely related kind that this project could benefit from association with.
- May have been enhanced with collaboration from industry groups.
- Should seek industry inputs.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.40** for proposed future work.

- Work duplicates other efforts.
- Needs external input to define scenarios to be studied.
- Need to improve transport aspects, e.g., pipeline between regions, other that just cryo-trucking.
- Should apply to other renewables and explore synergies.
- Future plans lack specificity.
- Agree that proposed future work in this area is minimal/limited.
- Inclusion of a "biomass as a source of H_2" should proceed with caution, since its commercial - ready status is very different from wind power.
- The term "biomass" should be clearly defined.

Strengths and weaknesses

Strengths

- Great presentation of wind market and alternative uses for wind.
- Excellent use of micro-modeling.
- Model should be very useful in application to other intermittent and scenario analyses.
- Well thought out analysis.
- NREL is best suited to do this study.
- Straight forward conclusions.
- Good discussions in the "conclusions" slide.

Weaknesses

- Ran out of time - skipped slides.
- Why "analyze" to 2050?
- The fact that this was developed as a wind model and then H_2 production was added seems to limit the usefulness of the results.
- It seems hydrogen "face-lifted" to wind.
- Wind should not be studied independent of other intermittents.
- There are potential synergies with other intermittents, e.g., hydro, photoelectric, biomass (where wind sites are forests or farms). These synergies are significant.
- Overly simplistic representations of argument.
- Not clear how results from other related Production projects feed into this study. It was hard to follow because of the "flip flopping" between wind electric generation and hydrogen production.

Specific recommendations and additions or deletions to the work scope

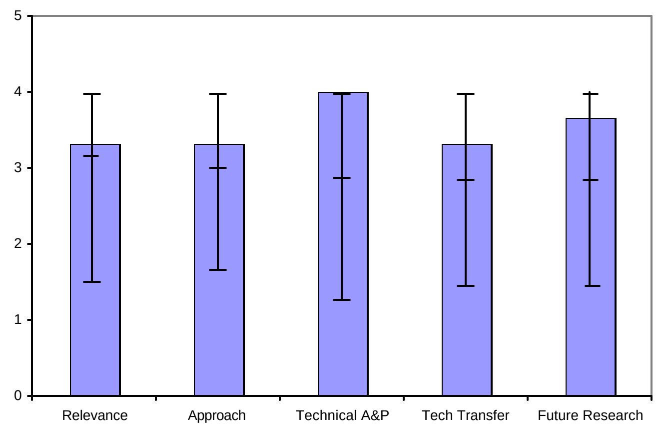
- It appears scope of project has been completed.
- Expand to include other intermittents.
- Explore synergies.
- Cancel this project.
- Explore synergy with solar and biomass methods of H_2 production to give a load leveled system.

Project # HPD-P1: Novel Catalytic Micro channel Fuel Processing Technology
Irving, Patricia; InnovaTek, Inc.

Brief Summary of Project

The goal of this project by InnovaTek, Inc. is to produce pure hydrogen from infrastructure fuels using cost-competitive, highly efficient catalytic steam reforming and membrane separation technology by: optimizing InnovaTek's proprietary steam reforming catalyst composition; optimizing the hydrogen-permeable membrane composition and operating procedures; developing efficient thermal management using micro channel heat exchangers and an internal burner; and integrating processes and components to achieve smallest size and most efficient thermal management.

Overall Project Score: 3.53



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Looks like a good approach for distributed hydrogen production.
- Clear relationship to DOE objective.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- The current first phase of this project has now been successfully completed.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **4.00** based on accomplishments.

- It looks like they are making good progress in all areas.
- 3 ppm S diesel unrealistically low.
- Cost efficiency and longevity targets will be met.
- The now completed first stage development has led to a multi fuel process for generating H_2 utilizing: 1) a novel micro channel reactor with good heat transfer characteristics. 2) a sulfur resistant catalyst and 3) a effective H_2 membrane unit.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Much of the creative engineering work seems to have been done internally.

- Outside contracts have been utilized for marketing their product for which they appear to have customers.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.67** for proposed future work.

- Close to commercialization.
- The PI had outlined a good forward plan for a second phase of this project: mostly operating system integration work and economics refinement etc. for the construction of a commercial prototype.

Strengths and weaknesses

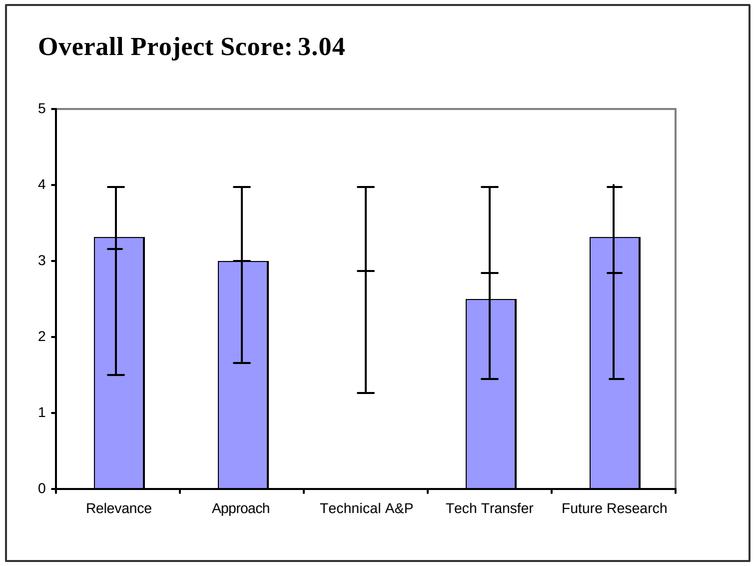
Strengths
- Impressive progress for a very small company.
- Technology can be useful short term and far into the future.
- Very creative innovative engineering work.

Weaknesses
- Will the company have the low cost, large scale manufacturing capability to put this fuel production unit completely in the market place? (A question for the stage 2 proposal).

Specific recommendations and additions or deletions to the work scope

- A follow-up stage 1 should be seriously considered.

Project # HPD-P2: Startech Hydrogen Production
Lynch, David; Startech Environmental Corp.



Brief Summary of Project

Startech Environmental Corp. will field test integrated hydrogen production on a pilot scale using plasma gasification and ceramic membrane hydrogen separation, and evaluate commercial viability and scalability through extended operation under representative conditions.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.33** for its relevance to DOE objectives.

- Dual function-disposes of waste and provides moderate size H_2 production.
- To the extent that this technology actually encourages distributed H_2 production from biomass and non-natural gas feedstocks this project is very well targeted.
- Questions: feedstock availability; variety; on-site H_2 storage; safety; not sufficiently addressed.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Method appears attractive, all steps appear feasible, membrane porosity may be more reasonable than ICCM.
- Not clear whether the technology of plasma-based conversion works efficiently across a wide range (as claimed) of organic and fossil based inputs (feedstocks).

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **N/A** based on accomplishments.

- The project has not yet been initiated.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Too early to evaluate.
- The project does not appear to involve participation with or integration with other industry or university performers or National Labs - at least that is the impression given by the posters and in oral comments by representatives.
- No apparent collaboration with other organizations, possibly none needed.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Concepts look good.
- Presentation could do a better job of explaining how, technically, the wide variety of potential feedstocks - particularly if a mixed feed, is converted into high purity hydrogen, as well as how slagging and other unwanted by-products are minimized.
- All work presented is future work.

Strengths and weaknesses

Strengths

- The project goals and the SOW are ambitious, yet quite feasible and achievable ultimately in commercial applications.
- Technically, the design and operation of the gasifier lends itself to 1) a wide range of feedstocks; 2) simple single stage gasification 3) low volume of ash, slag gaseous emissions etc., and 4) easy scalability for varied applications.

Weaknesses

- Not clear that a rigorous enough analytical program is in place to assess the impact on efficiency and H_2 volume and purity of using mixed feedstocks.
- More attention needs to be given to "real life" availability of feedstocks, issues of volumetric output and storage for a range of particular applications.

Specific recommendations and additions or deletions to the work scope

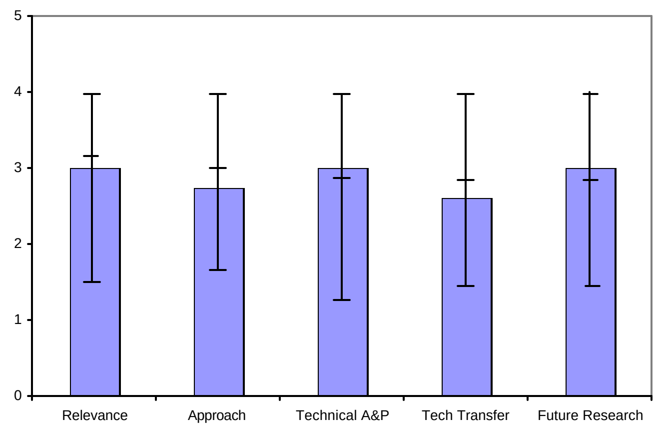
- Extend the non-technical reach to encompass the interface between gasifier performance and the broader system components of both feedstock issues and end-use applications.

Project # HPD-P3: Water-Gas Shift Membrane Reactor Studies
Killmeyer, Richard; National Energy Technology Laboratory

Brief Summary of Project

In this study project the National Energy Technology Laboratory (NETL) will evaluate water-gas shift (WGS) reaction kinetics and membrane flux using industrial gas mixtures and conditions, test the feasibility of enhancing the WGS at high temperature without added catalyst particles by using a membrane reactor, and determine the catalytic effect of metal shell materials (e.g., Inconel) and membrane surfaces (e.g., Pd) on the WGS reaction.

Overall Project Score: 2.87



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- This technology will be applicable to the barriers when better WGS membranes are available.
- Difficult to see direct relationship to DOE objectives.
- Objectives meet mission.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- This project tests water gas shift membranes, while other projects develop membranes.
- Need to show linkage to other projects with membrane development for WGS or have standard methods for evaluation: or predict impact of membranes.
- Little hydrogen above equilibrium seems to be produced. However, high temperature means high cost of operation and major capital costs-these should be estimated.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Small project.
- Baseline results.
- Good measurement - supports models, more realistic tests.
- Little production above equilibrium.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.62** for technology transfer and collaboration.

- Need better linkage with large Hydrogen Production/Delivery projects that could use WGS membrane tests.
- Only collaboration seems to be with the local university.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Provides incremental improvement only - if that.
- Not likely to provide a major breakthrough.

Strengths and weaknesses

Strengths
- Very good methods and equipment.
- Great concept; promising if hurdles can be overcome.

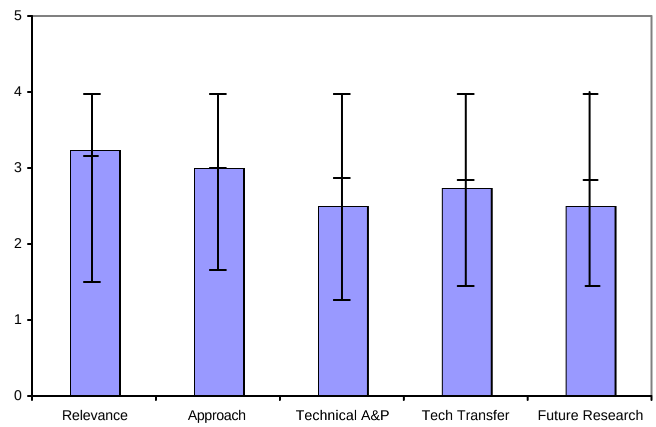
Weaknesses
- Linkage and/or overlap with other projects.
- Many potential problems that could prevent commercialization of technology.

Specific recommendations and additions or deletions to the work scope

- Need to determine effect of contaminant in coal gasification stream early.
- Compare with conventional high-T shift followed by low-T shift.
- Consider Pd alloys for decreased cost.
- Perhaps help establish baseline measurements for production membranes and WGS membrane reactors.
- Estimated costs should be determined relative to estimated H_2 production.

Project # HPD-P4: Fluidizable Catalysts for Hydrogen Production from Complex Feedstocks
Magrini-Bair, Kim; National Renewable Energy Laboratory

Overall Project Score: 2.80



Brief Summary of Project

The objective of this project is to develop and demonstrate technology to produce hydrogen from biomass at $2.90/kg by 2010 and to make it competitive with gasoline by 2015. The approach is to identify the best industrial reforming catalyst and catalyst support and to formulate, evaluate and optimize multifunctional, multicomponent catalysts. To date they have developed novel fluidizable reforming catalysts with CoorsTek ceramics with improved reforming activity.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.25** for its relevance to DOE objectives.

- Disposing of waste while generating H_2.
- Multiple feedstocks possible.
- Biomass/waste for "renewable" based hydrogen.
- Primary effort is biomass technology rather than 100% hydrogen production.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- A fairly modest goal -- improve (less attrition) catalyst.
- “Sister” project to HPD-P5 and -P7.
- Develop robust (strength-durable) catalyst for fluidization -- test commercial catalysts and supports.
- Focused on one issue -- attrition increases chance of success.
- Applies to multiple applications, but is this only or deactivation cause.
- Again, little thought for high hydrogen production.
- Focused on attrition. Is this the only problem or is catalyst deactivation a greater problem?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- A very long project FY 01-FY 09?
- Large budget decrease to small project.
- Hard to see "improvement" through the FY 03-04 data.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.75** for technology transfer and collaboration.

- Moderate - other than Coors- vendors, 1 article, 1 patent application.
- Increased industrial links: planned patent and license discussion.
- Chief aim is advanced biomass pyrolysis techniques not hydrogen production and therefore does not support the President's Initiative.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Project should be completed well before planned FY 09.
- What are targets and goals? "Evaluate" and "improve."
- Not likely to lead to major technology breakthroughs for hydrogen production.

Strengths and weaknesses

Strengths
- Broad approach - good testing facilities, potential for "rapid testing."
- Tests of multiple feeds is a plus.
- This project supports development of catalysts for advanced pyrolysis but does not really support hydrogen production.
- Project is well done.

Weaknesses
- Unsure if goal is good performance with little attrition and if so, what is the target.
- Data is from multiple feeds and conditions.
- Unsure what is the improvement seen in FY 03/FY 04, i.e., measured performance but was it "better," what was baseline, and how much improvement is targeted?
- You can test near catalysts forever. So what is the goal for here?
- Unlikely to provide a major breakthrough in hydrogen production.

Specific recommendations and additions or deletions to the work scope

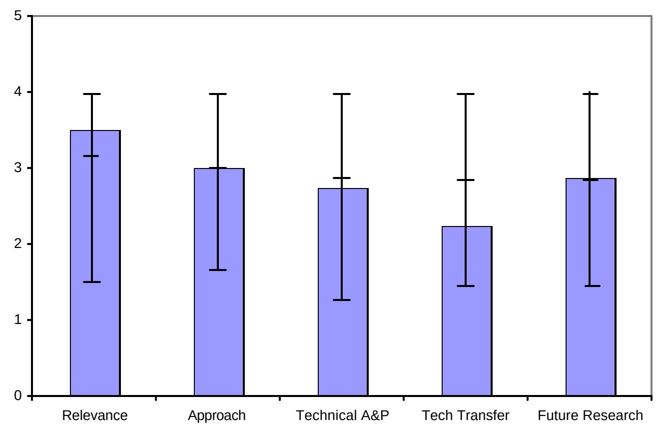
- Continue this research focused on a vital part of the future fuel issue -- converting a variety of hydrocarbon wastes to low molecular weight fuels.
- Projects -P7, -P4, and -P5 should be combined to one project and one funding source.

Project # HPD-P5: Hydrogen from Biomass: Process Research
Czernik, Stefan; National Renewable Energy Laboratory

Brief Summary of Project

This project explores the feasibility of producing hydrogen from renewable feedstock to increase flexibility and improve economics of a biomass to hydrogen process. The goal is to develop and demonstrate technology for producing hydrogen at 2.90/kg by 2010. The approach being used is pyrolysis or partial oxidation and steam reforming of biomass, plastics, and other solid organic residues.

Overall Project Score: 2.88



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Addressing two problems: hydrogen production and waste disposal.
- Strong clear linkage to multi-feed issues near to mid need.
- Valuable work.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Good two stage process.
- Potential of co-product value from pyrolysis may improve costs and be useful in the transition but coproduct dependency limits the amount of hydrogen that can be produced when a lot is needed in the hydrogen economy.
- Although this project discusses hydrogen production by pyrolysis/reforming the other gases also formed are not indicated - a separations problem.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.75** based on accomplishments.

- A relatively small project.
- Still needs work to meet DOE targets.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.25** for technology transfer and collaboration.

- Collaboration not apparent.
- Need more links with industry especially power, H_2, etc.

- Need catalysts links across projects.
- Tech transfer does not appear to be a major consideration.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.88** for proposed future work.

- Which catalysts are "best?"
- More of the same - just testing other biomass types.

Strengths and weaknesses

Strengths
- Tests, good experiments, near term.

Weaknesses
- This is a transition technology - needs to push to market in next 10 years.
- Sensitivity to co-product price as co-product market is saturated.

Specific recommendations and additions or deletions to the work scope

- Address mixed polymer wastes.
- How will PVC, nitrogen containing polymers be addressed?
- Is <1% catalyst attrition in 170 hours adequate?
- Can you claim a credit for disposing of wastes or does trap grease separated plastic have an economic value?
- Projects -P7, -P4, and -P5 are aspects of the same project and should be combined -- providing only one funding source for all.

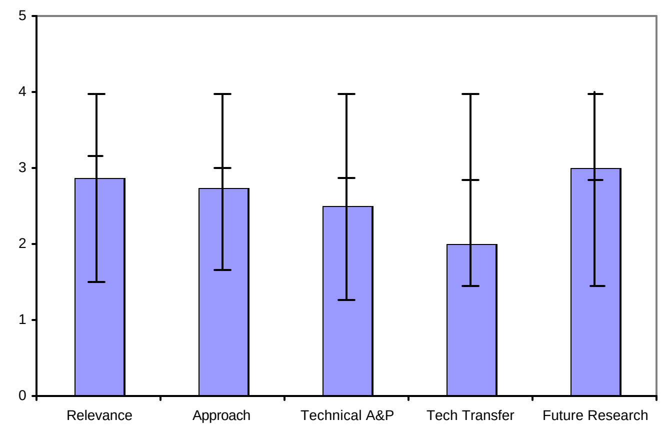
Project # HPD-P6: Aqueous Phase Catalyzed Biomass Gasification

King, David; Pacific Northwest National Laboratory

Brief Summary of Project

Pacific Northwest National Laboratory (PNNL) will develop a cost-effective method for the distributed conversion of biomass feedstocks to hydrogen, using the following potential feedstocks: (1) ethanol, glycerol; (2) sugars, sugar alcohols (xylitol, sorbitol, glucose); and (3) less refined starting materials such as cellulose or hemicellulose. In addition, PNNL will provide technical and economic comparisons with alternate biomass conversion approaches.

Overall Project Score: 2.63



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.88** for its relevance to DOE objectives.

- Valuable work.

Question 2: Approach to performing the research and development

This project was rated **2.75** on its approach.

- Stated funding inadequate for the outlined project.
- What is the feedstock availability?
- Looks like thermodynamics are unfavorable.
- Looks like reactor productivity too low needs to be increased.
- Combinatorial approach good.
- Aqueous gasification is very interesting.
- What is clear focus goal for this project?

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- New start - appreciable data.
- Two small projects successfully linked.
- Limited progress due to limited time and money.
- Project limited financially.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.00** for technology transfer and collaboration.

- Need better links to catalyst and gasification industry.

<u>Question 5: Approach to and relevance of proposed future research</u>

This project was rated **3.00** for proposed future work.

- It will be good to "close" off longer carbon chain materials for steam reforming and allow focus on ethanol and glycerol and output of aqueous gasification.

<u>Strengths and weaknesses</u>

<u>Strengths</u>
- Good and potentially stronger combination of two projects.

<u>Weaknesses</u>
- "Real" biofeedstocks will not be pure sugars, alcohols. (If purified -- they are too valuable) but mixtures including slurries.
- How will aqueous-metal catalyzed-gasification work on slurries?
- No real biomass has been examined -- project is very new and underfunded/poorly funded.
- Other potential off gases are not addressed.

<u>Specific recommendations and additions or deletions to the work scope</u>

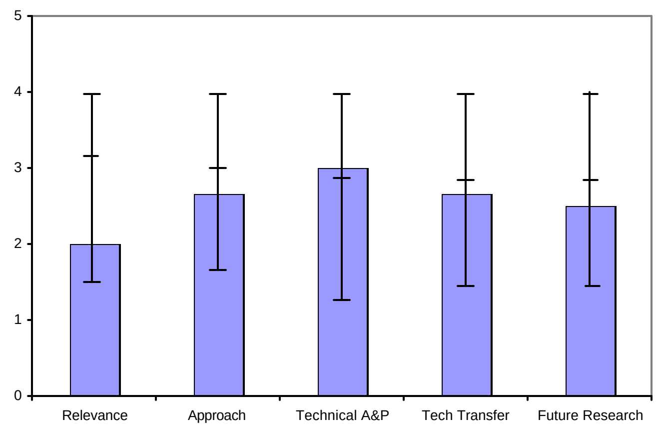
- Don't spend too much time on pure compounds, more on the real waste streams.
- Set goals for achievement -- more than "improve?"
- Process economic estimates are good but every small project cannot afford to do this - it becomes a management issue.
- Consider how to handle more realistic feeds (impure).

Project # HPD-P7: Hydrogen from Biomass: Catalytic Reforming of Pyrolysis Vapors
Evans, Bob; National Renewable Energy Laboratory

Brief Summary of Project

In this project, the National Renewable Energy Laboratory (NREL) evaluated the production of hydrogen from biomass by pyrolysis, steam reforming for $2.90/kg by 2010 and its barriers. Their milestone is to verify advanced catalysts and reactor configuration for fluid bed reforming of biomass pyrolysis liquid at pilot scale with catalyst attrition rates of < 0.01%/day by the fourth quarter of 2009.

Overall Project Score: 2.57



Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- This is a technique for biomass pyrolysis - hydrogen production is only a byproduct.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- "Sister" project to HPD-P5 with similar issues.
- Two stage systems (pyrolysis then reforming) adds complexity.
- Relies on coproducts.
- Little hydrogen production.
- Appropriate for their objectives.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- A relatively small project that has been downsized from the original larger one.
- Appeared to have success in the economic study but it was unclear.
- What is/was baseline cost?
- What is improvement needed?
- Good engineering design for "pilot."
- Technical accomplishments are not related to hydrogen production advancement.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Strong collaboration with UGA, Clark Atlanta projects.

- Weak apparent links with industry that might ultimately commercialize the technology.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Actual tasks are goals for them.
- Appropriate for their objectives.

Strengths and weaknesses

Strengths
- Mid-term technology with co-products.
- Char co-product is value also -- carbon sequestered.

Weaknesses
- Transitional H_2 production entry -- is there a real midterm opportunity?
- Full use may/will saturate co-product markets.
- Economics driven by co-products.
- In reality, this is a carbon/phenolic process that produces hydrogen as a byproduct.
- This work has been funded for years with little advancement in the technology and few breakthroughs.

Specific recommendations and additions or deletions to the work scope

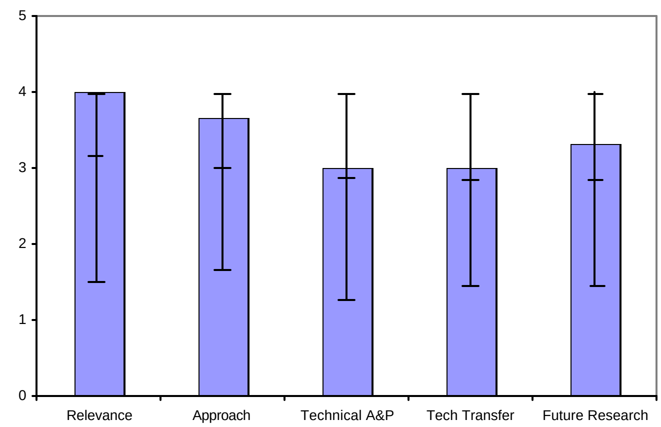
- More clearly state targets for improvement.
- Projects -P4, -P5 and -P7 should be combined with one overall project manager and 1 budget for all activities as they seem to be addressing different aspects of the same technology.
- Not an appropriate part of the hydrogen program.
- May be better fit with other DOE programs.

Project # HPD-P8: Creation of Designer Alga for Efficient and Robust Production of H_2
Lee, James; Oak Ridge National Laboratory

Brief Summary of Project

In this project, Oak Ridge National Laboratory (ORNL) will create a designer alga by designing and inserting a proton channel into the algal thylakoid membrane. This work will move toward overcoming the low rate of hydrogen production in photobiological systems.

Overall Project Score: 3.40



Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Relevant to renewable H_2 goals.
- Claims that work will meet goals.
- One research project addresses 4 barriers to biological production of H_2.

Question 2: Approach to performing the research and development

This project was rated **3.67** on its approach.

- Very creative approach.
- Sharply focuses on various schemes for hydrogen channel.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Good results considering funding level.
- Although poorly funded, the project has made progress.
- Good performance given limited funding.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Good collaborations within ORNL and with academics.
- Working with University of California, Berkeley, etc. to solve all algae issues.
- Investigator plans to work more closely with University of California, Berkley and NREL.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Plans are good, but funding is low for plans.
- Future research, bulk of project, is sharply focused to address 4 technical barriers.

Strengths and weaknesses

Strengths
- Integrated, well thought out approach to algal synthesis.
- The project is currently poised to develop and test a new/modified catabolic manipulation -- if successful, it could produce a significant breakthrough in biological hydrogen production.
- Innovative and high potential.

Weaknesses
- No cost breakdowns or estimates.
- No attention to balance of plant or implementation.
- Limited funding.

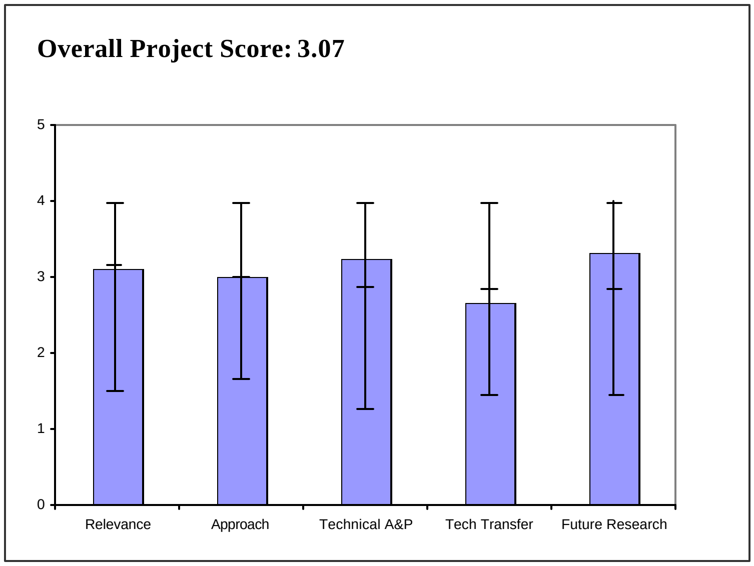
Specific recommendations and additions or deletions to the work scope

- Suggest that tie be formal with T. Melis having overall responsibility and control of the entire project.
- Have go/no-go decision point in two to two and a half years based on whether or not H_2 production increases.

Project # HPD-P9: Hydrogen Reactor Development and Design for Photofermentation and Photolytic Processes
Blake, Dan; National Renewable Energy Laboratory

Brief Summary of Project

This National Renewable Energy Laboratory (NREL) project's objectives for FY 04 are to identify three transparent material candidates, begin accelerated and outdoor weathering tests, and measure key properties for photolytic reactor applications. Solar production of hydrogen by photocatalytic or photobiological processes will require large area reactors with transparent coverings that have low hydrogen permeability.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.12** for its relevance to DOE objectives.

- Fairly routine work to evaluate coatings.
- Most of data should be tabulated.
- No real innovation.
- Development of coatings for reactors will be essential to production of efficient and durable reactors.
- Project timeline discusses fermentation - not an objective since light transmission is not an issue there.

Question 2: Approach to pe rforming the research and development

This project was rated **3.00** on its approach.

- Good to begin small effort in this area of transparent materials for construction.
- Can be kept small for now.
- Making the right initial measurements.
- Reasonable approach for testing polymer photostability.
- Could probably be assigned to contract lab and done for less money.
- Project leverages extensive NREL experience in coating materials to rapidly advance the specific research needs of this project.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Small project - just started.
- Materials tested.
- Progress is excellent utilizing minimal budget.

- Excellent start - using previous data.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- None yet.
- Is some existing member of the program already set up to test permeability and flux?
- Not really needed here.
- Project makes use of strong network of test sites.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- Good plan.
- Work should be expanded (more funding) or dropped.
- Work is a vital input to continued systems analysis of photoproduction systems.

Strengths and weaknesses

Strengths
- Essential for any photo conversion.
- Beginning to look at "coatings" -- may need to look at "maintenance" of surfaces.

Weaknesses
- Title is misleading as this is really "transparent materials of construction."
- It was unclear how much "existing" data could be used.
- Really more of a routine "analytical" project than a real research project.

Specific recommendations and additions or deletions to the work scope

- Better define "issues" -- target properties of H_2 and O_2 permeability strength, brittle, transparency (and aging).
- Discuss baseline material(s), if any.
- In later stages of this work the PI and staff should be strongly encouraged to work very closely with photobiological and solar electrochemical experts to ensure that the reactors for each type of application are appropriate for that specific application.

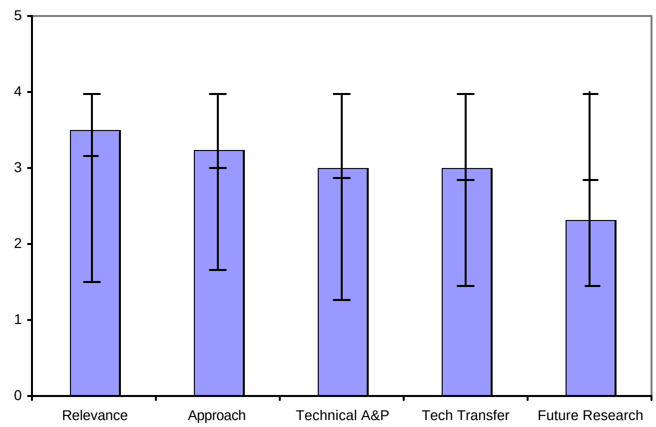
Project # HPD-P10: Photoelectrochemical H_2 Production Using New Combinatorial Chemically Derived Materials

McFarland, Eric; University of California, Santa Barbara

Brief Summary of Project

In this project, the University of California, Santa Barbara designed and built a system for automated electrochemical synthesis of combinatorial libraries of mixed metal oxides with the objective of finding an appropriate material to use in the photoelectrochemical splitting of water to produce hydrogen.

Overall Project Score: 3.02



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.50** for its relevance to DOE objectives.

- Renewable energy sources of H_2 are a principal objective of the Hydrogen Program.
- Development of a direct conversion of solar to H_2 without several PV and electrolyzer components would be a great benefit if it is safe and economically viable.
- Deserves work in basic materials science.
- Difficult to see relationship to major DOE objectives.
- Hydrogen production from renewable energy sources is critical to a hydrogen - based energy economy. Clearly, the discovery of new photocatalytic materials is a necessary precursor toward that goal if efficiency improvements are sought for electrochemical production of hydrogen.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Work is located in a highly developed chemistry research environment.
- Keeping the work products focused on H_2 production will be a continuing challenge as well as maintaining communication with entrepreneurial companies with knowledge and willingness to develop the good ideas further.
- The experimental work lacks the complementarity that should be achieved with the advent of theoretical/computational studies to validate results and to obtain a more fundamental understanding of the material properties.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Development of research tools as methods to test photochemical properties has been good and scientific data from materials assembled and tested with tools validates methods. But, like basic materials research in many fields, the breakthroughs are sparse.

- Economic estimates needed to judge viability of approach.
- Project team has done a thorough job at characterizing material properties (experimentally).
- The work encompasses a remarkable amount of engineering and methods development.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Needs some success that will generate impact; not unlike other materials research.
- Good mix of collaboration/interactions among universities and commercial companies.
- Project could benefit further from collaboration with notable US universities working in the field (e.g., U. of Arizona).

Question 5: Approach to and relevance of proposed future research

This project was rated **2.33** for proposed future work.

- Has designed tools and methods to do more.
- Didn't see evidence of big picture reviews for future work.
- These researchers know their field and can be trusted to direct their work but the cadre is small and dedicated and could grow inward if not exposed to outside collaborative/expertise occasionally.
- Contingency plans were not clearly described in the event that neither Fe-based or Zn-Co based materials meet the desired expectations.
- Need a better plan for exploring other systems.

Strengths and weaknesses

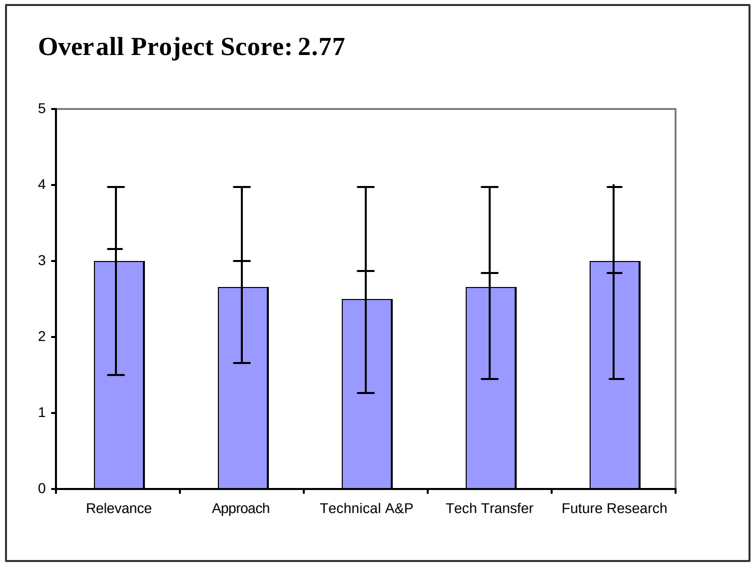
Strengths
- Materials science knowledge.
- Vision of importance of work.
- Research plan and premise of engineering effort are aimed at rapid screening and combinatorial alchemy of potential efficacious photocatalysts.
- Project team appears to be effective in fully characterizing the materials synthesized by the combinatorial methods/apparatus.

Weaknesses
- Basic materials research is not amenable to a fixed schedule.
- While the methods/apparatus are capable of producing a vast array of compositional variables, the overall effort seems to lack hypothesis-driven guidance or direction in terms of the composition-activity relationships, and theoretical component of overall effort is missing.

Specific recommendations and additions or deletions to the work scope

- Need to implement theoretical element of effort in order to compare experimental results with what theory can predict.
- *Ab initio* solid-state theory such as VASP, density functional theory, should be considered as a means of predicting band structure and photophysics.

Project # HPD-P11: High Efficiency Electrolysis Materials Research
Ingersoll, David; Sandia National Laboratories



Brief Summary of Project

Sandia National Laboratories (SNL) intends to improve the cell performance for electrolysis of water through improved catalysts and membranes. Specific objectives of the project are to prepare structured polymer thin films as novel low resistance, hydroxyl conducting membranes and evaluate their electrochemical performance as electrolyte/separator, prepare and electrochemically evaluate transition metal (e.g., Mo) macro cycle complex-based electrocatalysts, develop combinatorial catalyst discovery using direct assessment of electrochemical activity, and develop novel catalyst discovery through spatial correlation between localized electrochemical activity and catalyst composition/structure of more traditional electrocatalysts.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Improving the efficiency of electrolysis, assuming the principal energy source comes from a renewable form (e.g., solar) is important to the goals and objectives of the Hydrogen Program.
- The materials-related challenges, however, are great as they mirror those of the battery industry.
- Project is 1-2 months into work.
- Critical evaluation at this point may be premature.

Question 2: Approach to performing the research and development

This project was rated **2.67** on its approach.

- The synthetic scheme for Mo-based macrocyclic catalyst has significant technical barriers with regard to control of template quaternary structure and the simultaneous cross linking of monomer to form a highly conjugated, continuous porous structure.
- It is not even clear whether the PS template can be removed without destroying the macrocyclic framework.
- The synthetic pathway toward cross linking the monomer was not effectively described.
- It would seem prudent to first demonstrate using a readily polymerizable system that the approach toward forming a scaffold will work. Otherwise, the success of this project will be determined by what happens much later in the plan than earlier.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Not applicable.
- Too early in the project to judge.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.67** for technology transfer and collaboration.

- Too early in the project to judge.
- Only "potential" or internal collaborations were identified.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Its almost all future.
- The critical, proof of principle experiments will be conducted through the remainder of FY 04.

Strengths and weaknesses

Strengths
- Project plan represents high-risk though novel approach toward the development of highly porous electrocatalytic materials for water electrolysis.
- If approach for synthesis of electrocatalyst is successful, a similar tactic may be used in the development of similar electrocatalytic membranes for fuel cells or for petrochemical processes.

Weaknesses
- Experimental approach lacks details pertaining to the chemistry of cross-linking macrocyclic monomers.
- The success of the experimental approach relative to synthesis of electrocatalyst is determined too late in the program.
- No experiments have been planned to support proof of principle early in the project.

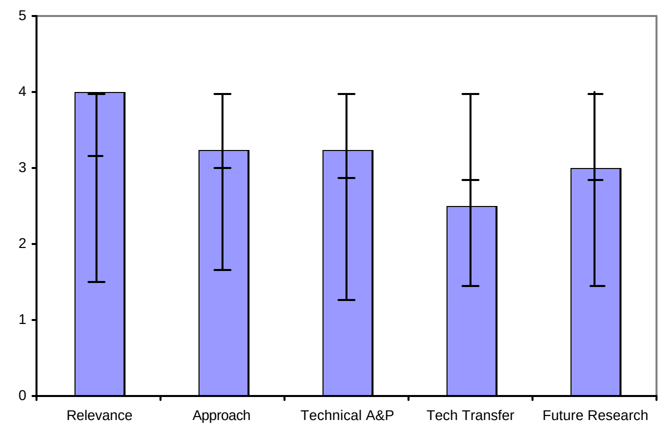
Specific recommendations and additions or deletions to the work scope

- Proof of principle experiments for the synthesis of electrocatalyst (cross-linked macrocycle) need to be conducted early in the project to determine whether or not PS template approach has any chance of success.
- A readily polymerizable system may be explored, such as a polyamide or a polyimide, to test approach.

Project # HPD-P12: Low-Cost, High-Pressure Hydrogen Generator
Cropley, Cecelia; Giner Electrochemical Systems, LLC

Brief Summary of Project

Overall Project Score: 3.20



Giner Electrochemical Systems, LLC has an overall project goal of developing and demonstrating a low cost, high-pressure water electrolyzer system, which will eliminate the need for a mechanical hydrogen compressor, increase electrolyzer hydrogen discharge pressure to 5,000 psig, and demonstrate a 3,300 scfd high pressure electrolyzer operating on a renewable energy source. Past Year (Jan 03- Mar 04) tasks included the development of lower cost materials and fabrication processes for stack components, fabricating and demonstrating an electrolyzer stack and system producing hydrogen at 2,000 psig, and designing and fabricating a test stand for 5,000 psig operation.

Question 1: Relevance to overall DOE objectives

This project earned a score of **4.00** for its relevance to DOE objectives.

- Electrolyzers will have a place in the hydrogen economy as a method of converting electricity from any source into H_2.
- May provide a commercial alternative for pressurization from rotating equipment.
- Compression is a big issue and this project addresses a high-potential way of addressing this issue.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Incremental approach is good.
- Component by component improvement in the electrolyzer will lead to steady progress in overall performance. A strong approach.
- Focused approach on demonstration of feasibility and reducing cost.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Stack cost reduction on track.
- Found lower cost materials, reduced compound count. But significantly impacted unit cost.
- Increased operating pressure two-fold good progress in first year. Another 2-fold in second year will be excellent.
- Significant progress to lowering cost and demonstrating feasibility at increased pressures.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Collaboration with other designers/fabricators may be helpful.
- GM has substantial ownership stake in Giner, so collaboration with GM is essentially not a collaboration.
- GM gets to keep the technology funded with government money.
- Outreach program is nice but also not a collaboration.
- Consider/confirm collaboration with other research programs, for example Europe and Japan.
- Little collaboration.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Schedule is aggressive, hard to see how it can be accomplished.
- Likely to reach goals but next steps are somewhat ill-defined in the poster. This is probably due more to confidentiality rather than any weaknesses in capabilities of the researchers.
- Builds on past research and addresses overcoming barriers.

Strengths and weaknesses

Strengths

- Giner Electrochemical is a top candidate for breakthrough technological advancement, having more experience than most others.
- Trying to go from ambient to 5000 psi with no mechanical compressors will lower cost of the unit and push the limit of what can be done with high pressure electrochemistry.
- Interesting opportunity to replace mechanical compression.

Weaknesses

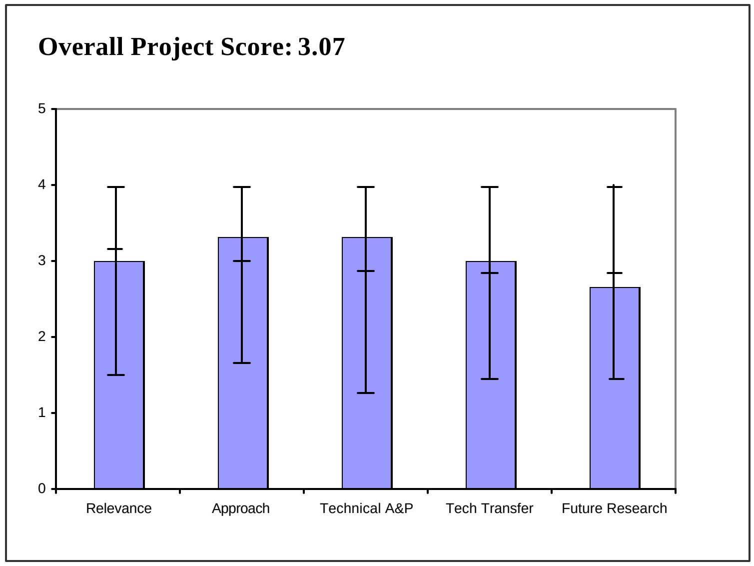
- No collaborations.
- Should expand in non-critical areas rather than doing everything alone.
- Proposed future research short on specifics, hard to evaluate.
- No optional paths identified.
- Little collaboration with universities, etc.

Specific recommendations and additions or deletions to the work scope

- We really need to get to 10,000 psi hydrogen.
- Consider feasibility of achieving higher pressures.
- Work on catalyst loading impressive but makes little impact on system cost (compared with balance of plant costs).
- Many researchers are working on catalysis, so need not be included in scope of this project.

Project # HPD-P13: Hydride Based Hydrogen Compression
DaCosta, David; Ergenics

Brief Summary of Project



The goal of this project is to develop a hydride-hydrogen compressor that operates in conjunction with advanced hydrogen production technologies and improves the efficiency and economics of the compression process. The objectives are to: continue testing a single stage hydride thermal compressor that employs three purification technologies to determine threshold contamination levels for common impurities; investigate compressor capabilities to perform the dual function of compression with purification for impurities that adversely affect fuel cell operation (e.g. CO); and develop miniature hydride heat exchanger manufacturing methods that will reduce cost to approach the 2010 cost targets.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- This is outstanding work, the reason for only a good rating is that the development of metal hydride compressors is not critical in meeting the President's Hydrogen Initiative goals like storage and lower cost.
- Alternative method for H_2 compression to reduce energy needed is important.
- This system is needed and will be needed in the future as hydrogen applications become more significant.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- The approach over the past several years has been outstanding.
- A version is near commercial status and they expect to make their first sale this year.
- They have one remaining challenge of removing methane. The PI explained their approach of raising temperature on the first discharge, which should solve the problem.
- Good approach based on background of hydrides for H_2 storage.
- Improved durability in the presence of impurities is important.
- Size of compressor needs to be reduced.
- Cost needs to be reduced.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.33** based on accomplishments.

- The metal hydride compressor shows superior performance over other methods of gas compression for H_2.
- Demonstrated removal of CO and moisture stability are good achievements.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- The company is a small business and has not collaborated to a large extent.
- The justification for the outstanding rating is with some collaboration and internal expertise they are very close to going commercial.
- Needs to work with fuel cell partner.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.67** for proposed future work.

- The PI indicates the project ends in this next year because they are close to success. They did not have a list for future research.
- The rating of good is based on the need for different sizes and pressure ranges to meet H_2 needs in compression in the future.
- Need to develop independent funding source for next phase.
- More cycling of material (hydride) is needed.
- Removal of CH_4 needs to be addressed.

Strengths and weaknesses

Strengths
- A near commercial success, the type DOE needs to keep their long range H_2 program on track.
- Necessary device for future hydrogen application.
- Ability to remove CO and H_2O from gas stream during compression.

Weaknesses
- Would have liked to see the company looking at different configurations of their concept of metal hydride compressors, so DOE in the out-years could continue to have success stories associated with funding.
- Bulky size -- needs to be smaller.
- Not enough cycling data.

Specific recommendations and additions or deletions to the work scope

- The recommendation is for DOE to keep its involvement in metal hydride compressors and not have it end next year.
- Reviewer had difficulty addressing cost-benefit plan for hydride compressor.
- Different engineering design is needed for the cooling and heating system.

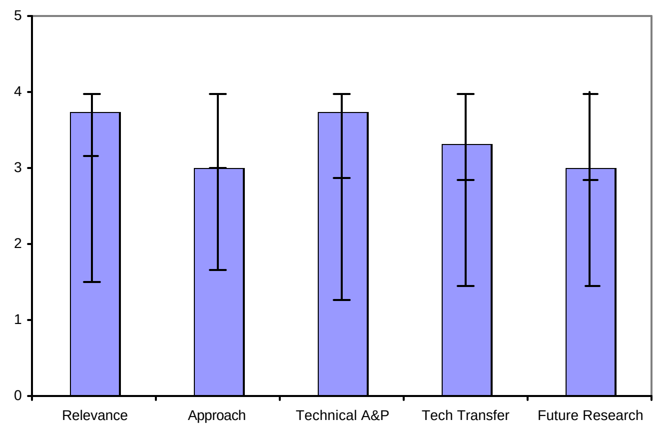
Project # HPD-P14: Technical and Economic Studies of Regional Transition Strategies Toward Widespread Use of H_2 Energy

Ogden, Joan; University of California, Davis

Brief Summary of Project

This University of California, Davis project will develop new simulation tools to evaluate alternative pathways toward widespread use of hydrogen under various demand scenarios and regional conditions. Tasks are to understand which factors are most important in finding viable transition strategies, to develop "rules of thumb" for future regional hydrogen infrastructure development, to conduct regional case studies of H_2 infrastructure transitions, and to work with the H_2A core group to develop models of hydrogen delivery systems.

Overall Project Score: 3.37



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.75** for its relevance to DOE objectives.

- Great communication and analysis tool.
- Very relevant for planning the transition.
- Identify how H_2 will enter the market best.
- Useful tool for analyzing the transition.
- Shareable excel model.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Very good but somewhat mechanical approach to demand.
- Needs a more robust demand model.
- Needs to consider other possible transitions- smaller vehicles.
- Not driven by price - price conservatism.
- Safety needs more attention.
- Well thought out and addressed barriers.
- Very good job of thoroughly thinking out the issues, starting simple and adding complexity.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.75** based on accomplishments.

- Model and engine very impressive for the budget; great work.
- Presenter was very impressive in understanding and dedication.
- Excellent progress considering the number of factors considered.

- Have produced a useful model that can evolve.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.33** for technology transfer and collaboration.

- Seems to share progress and much inputs.
- Working with H_2A.
- Good use of a variety of resources.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- Optimization seems misplaced.
- Build on existing work.
- A logical extension of the current work.

Strengths and weaknesses

Strengths
- Easily shareable basic model.
- Presenter has impressive understanding and dedication.
- Good slate of collaborators and good communication potential.
- Application of thorough, novel thinking.
- Probably one of the better modeling studies.

Weaknesses
- More attention needs to be placed on safety.
- Needs to consider other vehicle transition, a better understanding of demand and perhaps, price drivers.
- Optimization leads to ideal results.
- Model depends greatly on its assumptions.

Specific recommendations and additions or deletions to the work scope

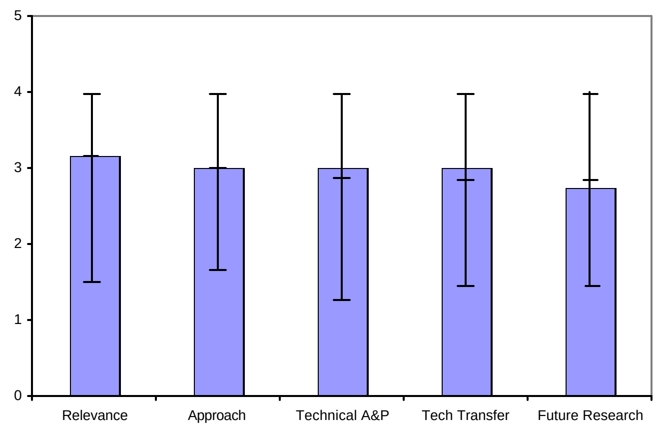
- Drop optimization for now. Replace with system dynamics study to understand how to improve system.
- Deserves support at maintenance level not an expansion level to see how the hydrogen and fuel cell vehicle transition evolves.

Project # HPD-P15: Hydrogen Production in a Greenhouse Gas Constrained Situation
Kartha, Sivan; Tellus Institute

Brief Summary of Project

Tellus Institute is examining in a detailed quantitative manner, plausible scenarios for a transition to a hydrogen economy. They will explicitly illustrate the staging and sequencing of major phases of the transition scenarios and their implications, quantify the greenhouse gas (GHG) reduction benefits of each of the transition scenarios, explore the spatial characteristics of the transition scenarios based on GIS analyses for four greater metropolitan areas of the USA (Boston, Denver, Houston, and Seattle), and account for relevant techno-economic and policy factors.

Overall Project Score: 2.98



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.17** for its relevance to DOE objectives.

- Model capable of key insights into dynamics of fleet transition.
- Focused on individual cities.
- Interesting compliment to other modeling efforts.
- End state focused.
- End state focus isn't quite as critical as transition.
- CO_2 impacts should be an important factor when considering a H_2 transition.
- Should produce a useful tool for assessing the transition.
- This study is important to the President's Initiative, since reducing CO_2 emissions is one of the big reasons for going to hydrogen. Pathway studies on CO_2 emissions from various types of hydrogen production are of great value to policy makers.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- These scenarios explored various scenarios.
- Assuming 90% fleet replacement by 2050.
- Needs to consider other cases besides National Energy Modeling System (NEMS) other economic /political scenarios.
- Not too much detail on internals of model.
- Approach seems good for examining infrastructure options in urban centers.
- Does current data warrant such detailed GIS mapping?
- Well thought out approach focused on modeling transition in a few cities.
- Appropriate for scope of the project.

- The PI appears to have uses the appropriate model and techniques so his findings can be integrated easily into DOE's internal assessments.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Model recall time keeps it from general use.
- Needs to track petroleum demand and other air transportation energy demand.
- Valuable tool for a municipality to get energy transition plans.
- GIS work adds little of analysis but is a serious point for municipalities.
- Not much info on progress in last year.
- Hard to evaluate.
- Significant progress toward project and DOE goals.
- Have produced some useful thinking on transition possibilities.
- The project appears to be near completion and is meeting the DOE goals for it.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Collaborations from specific cities should be brought into the loop.
- Coordination with H_2A is important.
- Work with a H_2A to develop assumptions- also with others on energy projections.
- Good use of H_2A results.
- I was not made aware of any collaborations with others.
- The good rating was based on the case of which this work could be transferred to DOE.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- More emphasis should be placed on alternative economic analysis.
- Environmental impact should be accompanied by energy and petroleum impact.
- Prices should be answer.
- Future direction not clear from poster.
- Focused on continuing previous work.
- Appropriate for completion of specified approach.
- The PI made only a fair case for continued support by citing that he would like to look at regional issues in more detail in the future.

Strengths and weaknesses

Strengths
- Well coordinated with NEMS.
- Addresses individual cities.
- Well thought out vehicle turnover model.
- Good GIS capability.
- PI knowledgeable in process used for program.

- Very focused on a few markets with detailed and various scenarios.
- Thorough work within the assumptions employed.
- Projection studies of this type are always risky; however, they do provide guidance to the decision and policy makers.
- This study did show limited to "no" CO_2 reduction when producing H_2 from fossil fuels.
- Comparative studies of this type allow planners to direct the available funds to the most appropriate production routes and distribution.

Weaknesses
- Too much dependence on NEMS.
- Municipalities should be part of collaboration.
- Not enough attention paid to energy and petroleum/gasoline offset.
- Project seems to be GIS capability in search of a mission.
- Limited number of cities investigated.
- Very dependent on assumptions, especially the definitions of the transition scenarios.
- Would have benefited from a more thorough vetting of transition scenarios as part of the collaborative process.
- Having ten to twenty year projections based on costs is troublesome to me. I would prefer to have these long range projections based on efficiency.
- The most efficient method of producing and transporting H_2 will be the best.
- Costs can be calculated or added into the model, if near term costing data is needed.

Specific recommendations and additions or deletions to the work scope

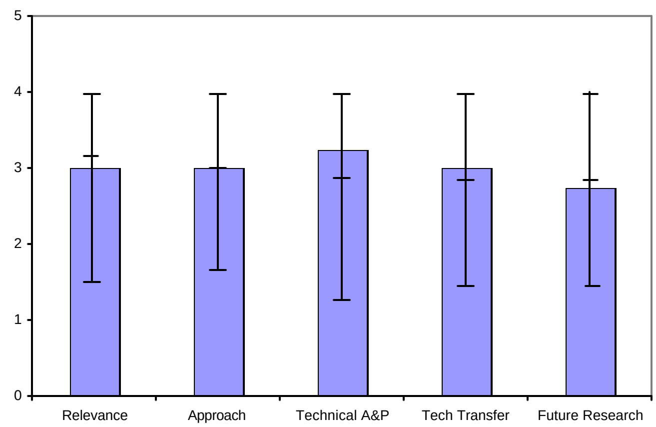
- Demonstrate to municipalities for comment and collaboration.
- Enable comparison with other fleet size/ vehicle evolution -- other economic political scenarios.
- Display petroleum/gasoline offsets in model results.
- DOE should continue to fund these comparative studies.
- These types of studies are needed for making sound decisions.

Project # HPD-P16: Fuel Choice for FCVs: Hydrogen Infrastructure Costs
Lasher, Stephen; TIAX

Brief Summary of Project

TIAX is conducting an assessment of the opportunities and risks for various fuel choices for FCVs –in particular comparing hydrogen to onboard reforming of gasoline. The assessment is also being used as a support to the refined R&D targets for direct-hydrogen FCVs based on an analysis of well-to-wheel energy use, GHG emissions, cost, and safety of direct-hydrogen FCVs and competing vehicle technologies.

Overall Project Score: 3.00



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Highly theoretical (by its nature).
- Useful to national effort but must be taken with a grain of salt.
- One of the few infrastructure economic modeling efforts.
- Studying how to best have hydrogen enter market-economics modeling.
- Should integrate more with ongoing DOE efforts (H_2A)-NEMS.
- Useful work to better understand the drivers for technology choices during the transition.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Difficult to tell a lot about details from poster.
- Investment return approach is valuable. Turns scenarios into cash value for potential investors.
- Good approach - would like to see scope expanded.
- Good recognition of the important components of assembling type of model.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.25** based on accomplishments.

- Difficult to assess quality of output, but is in general agreement with similar models.
- Plans to address areas where less is known and not based on natural gas reforming.
- Have assembled and done some refining of a comprehensive model.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Results should be validated with or incorporated into H_2A effort.
- Industrial entities should confirm component accuracy.
- Good collaboration/interface with industry - could involve more university.
- Having solicited and responded to stakeholder comments from a variety of parties.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.75** for proposed future work.

- Usefulness unclear.
- Work with H_2A.
- Good opportunity as long as it is well integrated with other DOE modeling efforts.
- Appropriate for project status.

Strengths and weaknesses

Strengths
- Good start at modeling H_2 transition.
- Model needs to be opened to public for validation.
- Adapting to meet program need and reflect more scenarios.
- Look at transition period, which may well be more significant to the development of a hydrogen economy than the long-term market.
- Includes all the necessary key components to adequately model the transition.
- Good job of soliciting and incorporating outside comments.

Weaknesses
- Modeling has limited usefulness.
- As usual, too many variables.
- Currently limited scenarios.
- As goes for any model of this type, it's only as good as its assumptions.

Specific recommendations and additions or deletions to the work scope

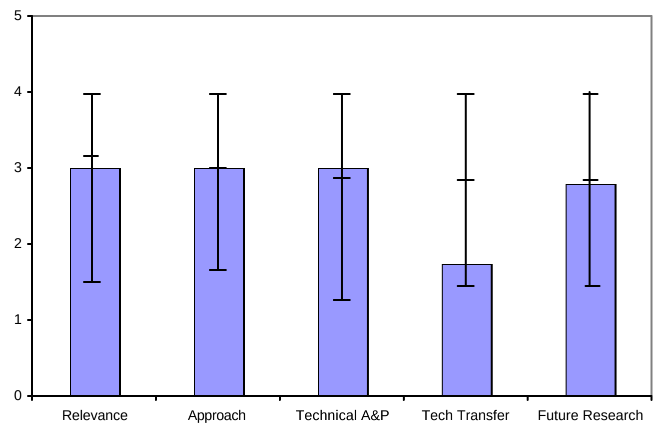
- This project should be funded at a relatively low level so that the model may be updated with new events.

Project # HPD-P17: New York State HI-Way Initiative
Hopewell, Paul; GE Global Research

Brief Summary of Project

Under this DOE contract, the GE Global Research's Hydrogen Production Team is researching methods to achieve considerable reduction in alkaline electrolyzer system costs, compared to prevailing prices of available new equipment. They will do this by technological advances, production methods, materials of construction, or a combination of these methods. Appropriate physics-based performance and cost models will be used to allow detailed trade-off analyses to identify practicable performance and cost solutions.

Overall Project Score: 2.71



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Efficient electrolyzers are obviously in the plan.
- Reducing cost of electrolyzer and resulting H_2 product are specific goals of the program.
- Very important to lower electrolyzer cost.
- Useful work on a technology that has been identified as key.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- No obvious novel idea for electrolyzers. Little novelty.
- Seemed to be a pretty routine materials and design selection process rather than any real research into how to make step-changes in electrolyzer design.
- Targeted approach appears to maximized progress during limited timeframe.
- Goal is to understand cost drivers and systematically pursue materials substitution and process improvements to drive capital and products costs down.
- Seem to be addressing technical barriers in a focused and logical way.
- Address the key elements of the DOE technical barriers.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- New project.
- Project is still beginning phases, hard to evaluate. However a good performance plan is evident.
- NA - Project began April 1, work started but no/few results available.

- Good progress - project began in April.
- Not applicable - new project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **1.75** for technology transfer and collaboration.

- May be too early to evaluate.
- Some stated collaboration with SUNY but actual value is not evident.
- No overt collaboration at tech transfer.
- Good use of collaboration - however much of the collaboration seems to be internal to GE.
- None identified, although it should be noted the project has just started.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.80** for proposed future work.

- Again, not sure of novelty of approach.
- Project scope is reasonably well defined.
- One year plan - bench scale demo at end of year and models.
- Further development outside this project.
- Future plans are less specific than they would ideally be however it is a very new project.
- Consistent with objectives and targets.

Strengths and weaknesses

Strengths
- Aligned with program.
- Presentation did not portray project objectives and specific scope well.
- Could not tell what was being done without aid of discussion with presenter.
- Goal is to use this project to seed a further development/ commercialization effort.
- Too early to comment.
- Really worthwhile project with excellent chance of lowering cost of electrolyzer costs.
- GE has good corporate range to address many of the barriers.
- Plan is for a comprehensive breakdown of electrolyzer manufacturing costs and how they can be reduced.

Weaknesses
- Pretty routine approach to making a step change.
- Safety approach limited to hazards assessment?
- Too early to comment.
- Not enough time on project to say.

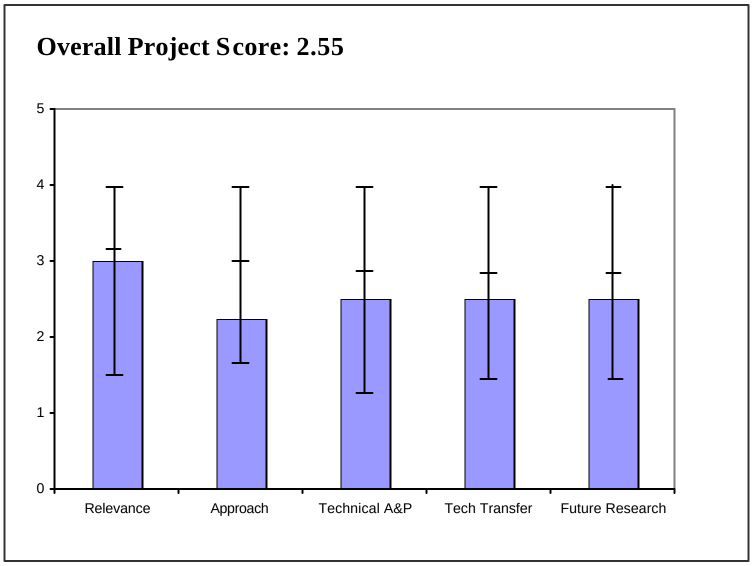
Specific recommendations and additions or deletions to the work scope

- None provided

Project # HPD-P18: EVermont Renewable Hydrogen Fueling Station
McKay, Chris; Northern Power Systems

Brief Summary of Project

Northern Power Systems is assisting the DOE in the development of hydrogen production technologies by building and testing a validation system. Objectives of the project are to: develop an advanced PEM electrolysis fueling station that utilizes renewable electricity sources; reduce cost of hydrogen production; improve electrolyzer efficiency; improve fueling station integration and controls; utilize hydrogen fueled vehicles for testing and validation; and show viability of distributed production pathway.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Objective is to rely on renewable sources.
- Flow chart integrates with electrical grid.
- How power output from wind will require use of grid.
- Grid for most locations is from non-renewable.
- Project allows partners to assemble integrated systems with (existing) advanced tech over current commercial offerings and get field-use validation.
- Demonstrates feasibility of H_2 production in near term.

Question 2: Approach to performing the research and development

This project was rated **2.25** on its approach.

- Other similar projects.
- No real new technology, but first integration of components in improved product.
- Re-assurable approach for electrolyzer-based fueling station demonstration.
- Not very R&D.
- Focuses on demonstration.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Too early in program to comment.
- Project cost is mostly a function of electrolyzer which is a separate effort.
- Project only began recently.
- Partnerships plan and budget established.

- Final contract not yet negotiated.
- Few technical barriers - though first of a kind.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.50** for technology transfer and collaboration.

- Consider/confirm collaboration with other similar projects to share "lessons learned."
- Good proposed team with industry leaders, well integrated.
- Should involve more university participation.

Question 5: Approach to and relevance of proposed future research

This project was rated **2.50** for proposed future work.

- Future work may be more commercial related as opposed to research.
- Plans appropriate for early stage of project - next year's review will be much more telling.
- Demonstration of H_2 distribution and production.

Strengths and weaknesses

Strengths
- Too early to evaluate.
- Near term demonstration of H_2 feasibility.

Weaknesses
- Too early to evaluate.
- Move demonstration in RD&D.

Specific recommendations and additions or deletions to the work scope

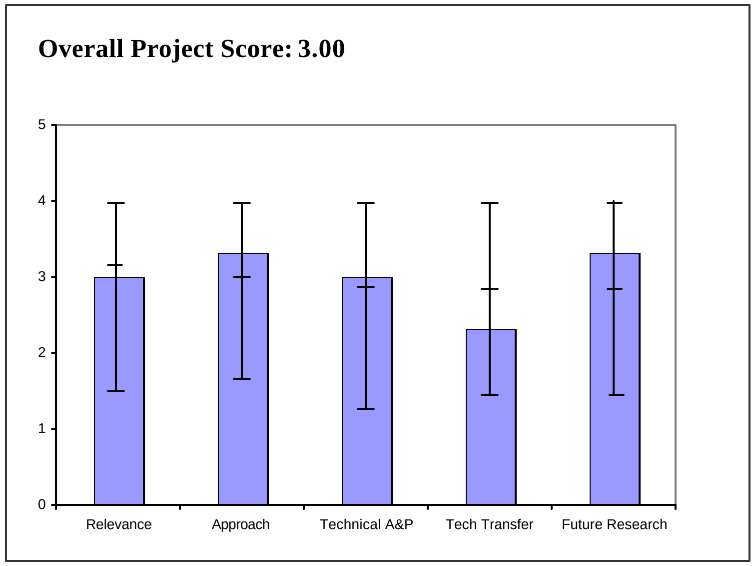
- None provided

Project # HPD-P20: Photopolymerization/Pyrolysis Route to Microstructured Membrane Development

Berchtold, Kathryn; Los Alamos National Laboratory

Brief Summary of Project

This Los Alamos National Laboratory (LANL) project will provide a rational approach to the design of synthesis processes for robust ceramic membranes with high gas permeability and gas selectivity at 1000C and higher. This novel route utilizes preceramic polymeric precursors while using established and economical polymer membrane fabrication techniques. The ceramic membrane is developed from the polymer membrane by a pyrolysis step adding another level of control over membrane permeability and selectivity.



Question 1: Relevance to overall DOE objectives

This project earned a score of **3.00** for its relevance to DOE objectives.

- Critical evolution at this time may be unwanted.
- This project may provide a new route to new materials for several different components.

Question 2: Approach to performing the research and development

This project was rated **3.33** on its approach.

- Excellent approach to exploring new materials.
- Confirm integration testing with various fuels.
- Good sequencing of acquisition of fundamental knowledge of capabilities of the technique followed by a more structured experimental design.
- Completion of these steps will establish framework to explore more targeted applications.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **3.00** based on accomplishments.

- Program not initiated until 04.
- Not applicable.
- Very good progress for such a new project.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **2.33** for technology transfer and collaboration.

- Collaboration not described - possibly none needed.
- No indications of any collaboration but that is not really a problem at this stage of this type of work.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.33** for proposed future work.

- It's almost all future work.
- Ambitious plan for the rest of the year.

Strengths and weaknesses

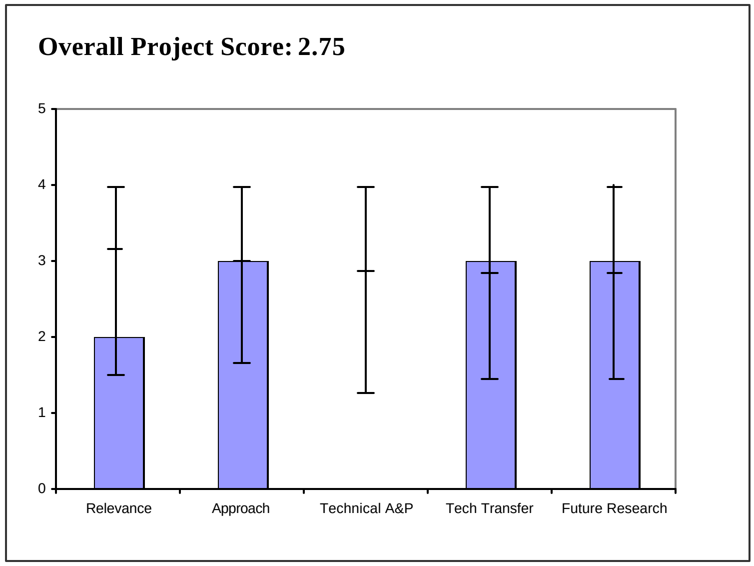
Strengths
- Novel approach that could yield novel materials.

Weaknesses
- May be attempting too much too quickly; some patience may be required in project management/ funding.

Specific recommendations and additions or deletions to the work scope

- As progress is made, collaboration opportunities should be identified.

Project # HPD-P21: Developing Improved Materials to Support the Hydrogen Economy
Shinkle, Robert; Edison Materials Technology Center



Brief Summary of Project

Edison Materials Technology Center (EMTEC) will use Hydrogen Program goals to identify and fund projects with near term commercialization potential, using cross-cutting breakthrough materials technology and application-specific tailored nanomaterials. State of Ohio matching funds are pending.

Question 1: Relevance to overall DOE objectives

This project earned a score of **2.00** for its relevance to DOE objectives.

- Difficult to see direct relationship to DOE objectives.
- Framework not inconsistent with the DOE plan; however, near term focus ignores the current state of the art considerations that drive the RD&D plan.

Question 2: Approach to performing the research and development

This project was rated **3.00** on its approach.

- Framework is there to provide useful contribution; too early to tell if the promise will be fulfilled.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **N/A** based on accomplishments.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.00** for technology transfer and collaboration.

- Not applicable.
- Project almost entirely collaborative - all of the work is essentially contracted out.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.00** for proposed future work.

- All work is future.
- Proposal is to sponsor useful work.

<u>Strengths and weaknesses</u>

<u>Strengths</u>

- Indicate a willingness to work closely with DOE to maximize value added to existing program.

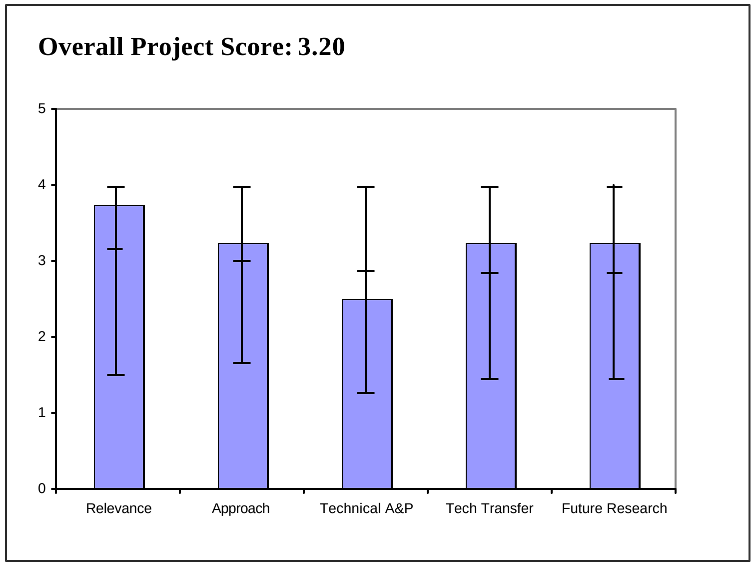
<u>Weaknesses</u>

- Too near-term focused; does not recognize the state of development of the vehicle and storage technology.
- Hard to see value added in having this contractor solicit and fund project proposals rather than DOE doing it directly.

<u>Specific recommendations and additions or deletions to the work scope</u>

- A more focused scope on materials would make more sense.
- If multiple areas should be pursued, perhaps this should be multiple projects.
- Change focus to longer-term; no immediate need for hydrogen production technology for the hydrogen initiative.

Project # HPD-P23: Hydrogen Generation from Electrolysis
Maloney, Tom; Proton Energy Systems



Brief Summary of Project

Proton Energy Systems and its team will determine pathways to optimum electrolysis-based H_2 fueling through conceptual system design and component/system development. They will develop the requirements for the fueling system, optimize fueling system designs through systems analyses, and conduct R&D to improve component performance, cost, and/or durability.

Question 1: Relevance to overall DOE objectives

This project earned a score of **3.75** for its relevance to DOE objectives.

- An integrated system incorporating renewables is vital to meeting the goals.
- Demonstration of a complete electrolysis package.

Question 2: Approach to performing the research and development

This project was rated **3.25** on its approach.

- Very well structured approach, good timeline, barriers being addressed.
- Have identified the key levers for optimizing this technology.

Question 3: Technical accomplishments and progress toward project and DOE goals

This project was rated **2.50** based on accomplishments.

- Project just starting. Results expected next year.
- Not applicable; project only just initiated.

Question 4: Technology transfer/collaborations with industry, universities and other laboratories

This project was rated **3.25** for technology transfer and collaboration.

- Consider collaboration with other similar projects.
- A well integrated team incorporating renewables, production process, and mechanical (storage compression).
- Have identified key collaborators knowledgeable in specific area.

Question 5: Approach to and relevance of proposed future research

This project was rated **3.25** for proposed future work.

- Look forward to seeing more.
- Good plan.
- Consistent with project approach.

Strengths and weaknesses

Strengths
- Very well integrated process.
- Knowledge leveraging among partners.

Weaknesses
- None provided

Specific recommendations and additions or deletions to the work scope

- This work is properly focused on the wind to H_2 car fueling issue.
- This effort is important to the National energy effort.
- Would benefit from DFM analysis of the entire system in addition to the planned volume manufacture analysis.